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Why new evidence says it's an oddball

EXOPLANET HUNTER
Kepler's best bits - by the mission scientists

IMPOSSIBLE STAR
+10 other objects that defy the universe

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Everything you need to know in 5 minutes

THERE'S SOMETHING WRONG WITH GRAVITY ...AND HERE IS ITS REPLACEMENT

FUTURE
ISSUE 083

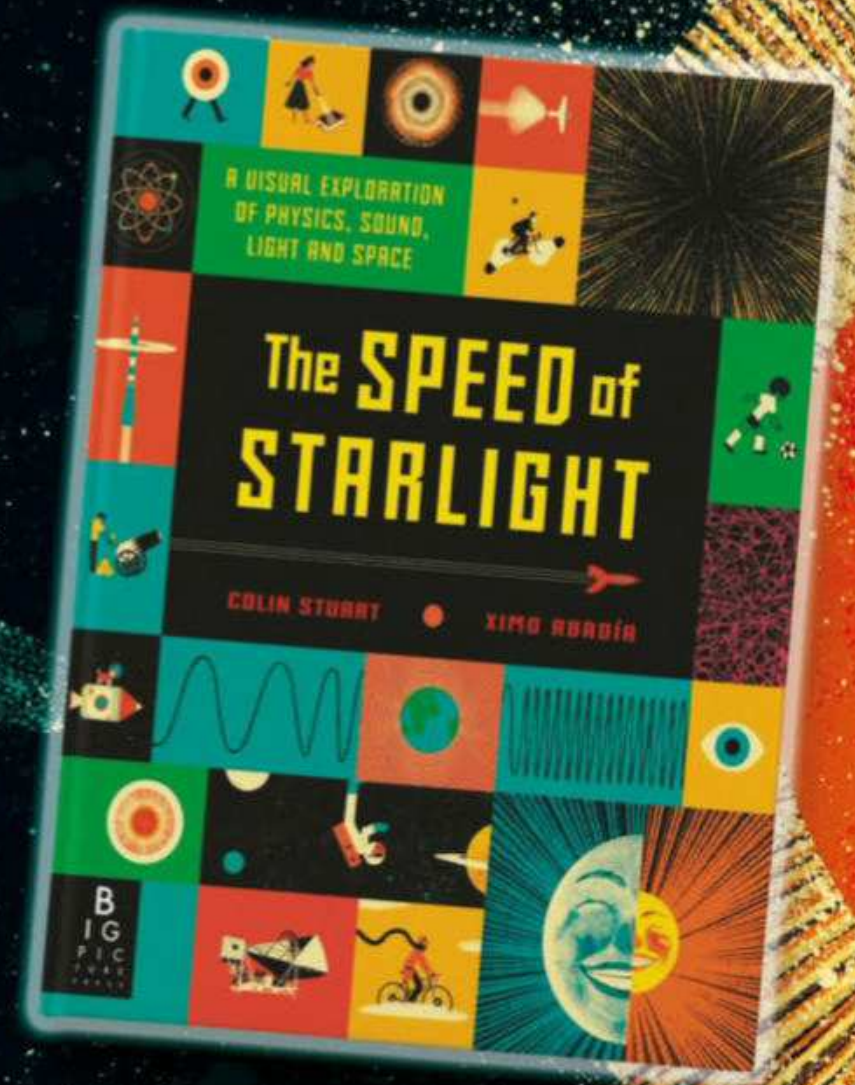
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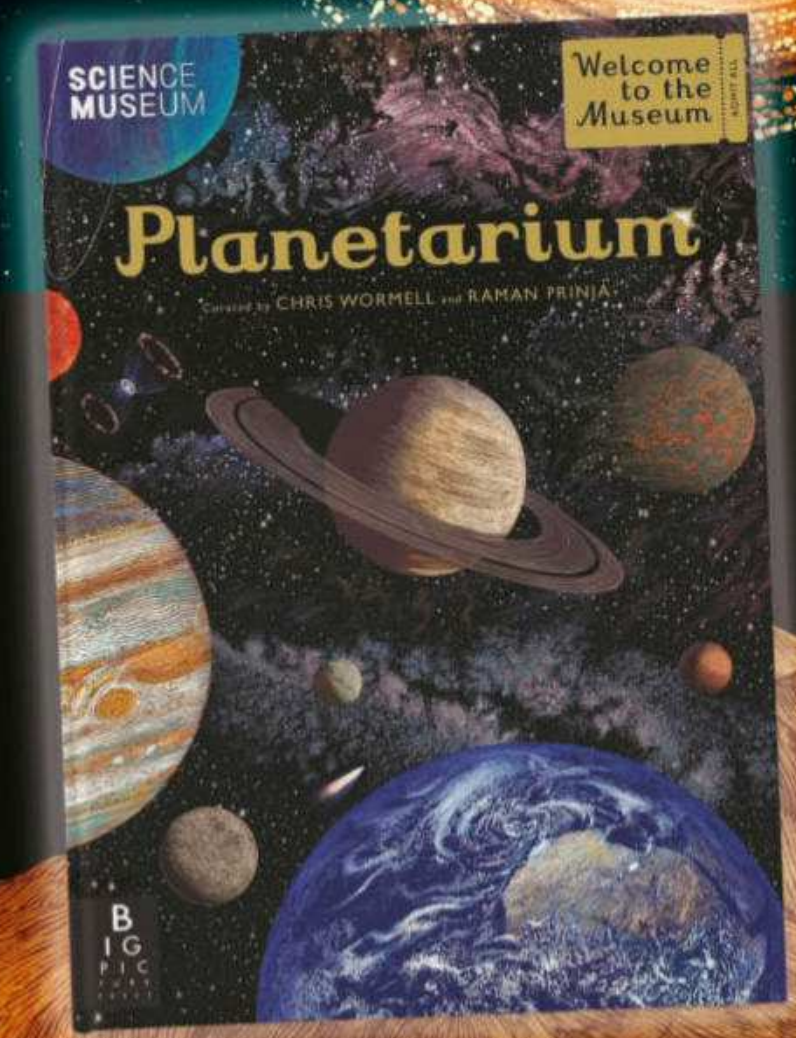
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Jupiter has been crowned the Solar System's oddball

© NASA/JPL-Caltech



Welcome

Observing season is here at last – and, as always, we've got plenty of guidance on the targets and spectacles that simply can't be missed, according to our team of astronomers. That's not all; we want you to get the very best from your observations, so we've compiled an easy-to-follow list that'll ensure that you become an even better stargazer this year. Turn to page 78 for our full night-sky guide for this season.

If you find yourself clouded out this month, then not to worry – we've got plenty to keep you entertained this issue. Discover how astrophysicists have realised that gravity doesn't make a great deal of sense in our understanding of the universe – and why they're proposing a replacement. Head over to page 16 for why the force that keeps us on the ground really doesn't make much sense.

Elsewhere, we've introduced a new section to the magazine – instant expert – which helps you to understand astrophysical concepts in five minutes or less. Let us know what you think! We've also recently reintroduced our Q&A section (formerly known as spaceanswers) to **All About Space**, where we get a panel of experts from the fields of space science, astronomy and space exploration to answer your questions. Got a question that you'd like answered? Send them into us over at space@spaceanswers.com, or on Facebook or Twitter!

Gemma Lavender
Editor

Our contributors include...



Abigail Beall
Space science writer
Gravity doesn't make a great deal of sense according to research, so astrophysicists have taken the decision to replace it – Abigail has the details on page 16.



Lee Cavendish
Astronomer & Staff Writer
Lee reveals the science fiction that assisted with our latest space technologies this issue – from hoverboard science to teleportation.



Colin Stuart
Astronomer & author
A star that shouldn't exist is puzzling astronomers – but that's not all. Colin gives the lowdown on other space objects that are defying the universe over on page 48.



Jamie Carter
Astronomer
Observing season is here and Jamie has the top tips you need to be a better stargazer, ensuring that you get the very best out of your views of the night sky.

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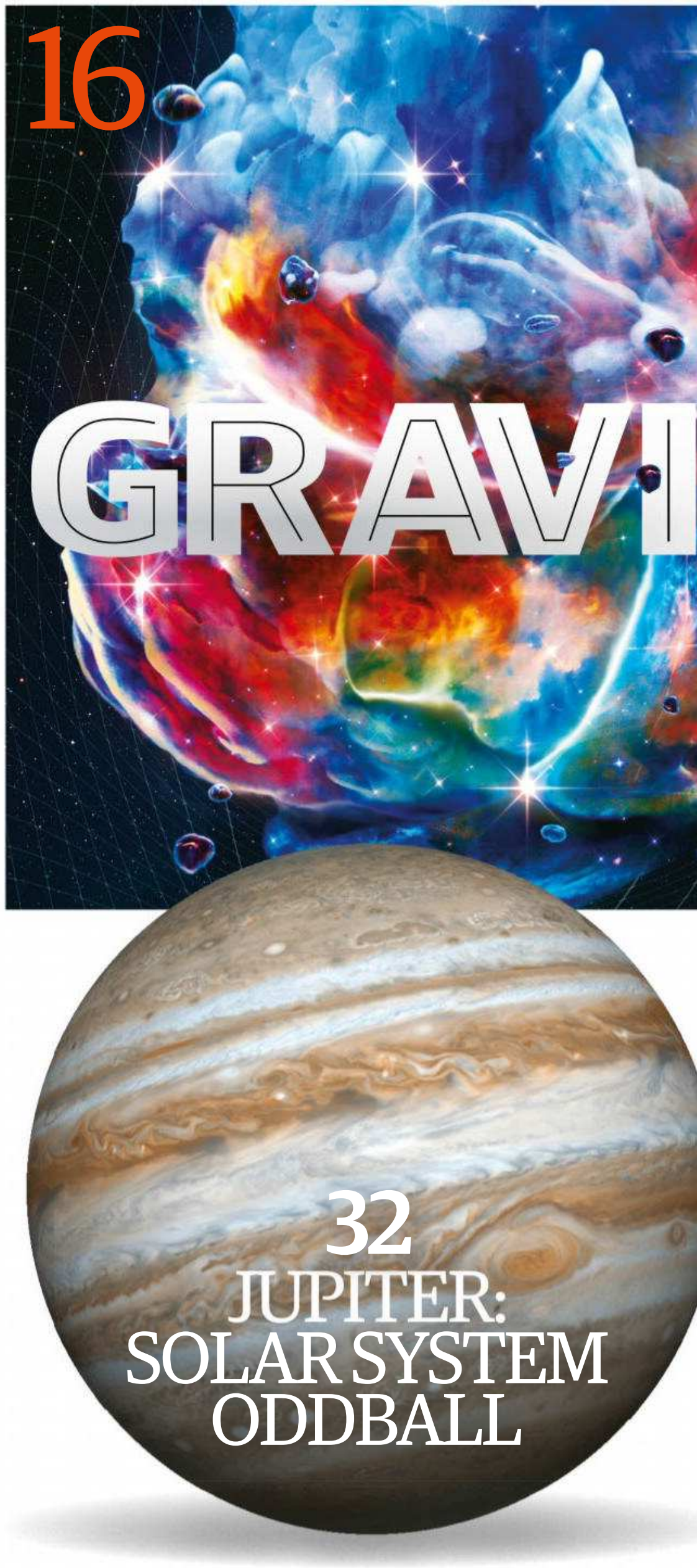
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Our experts answer your questions about the universe

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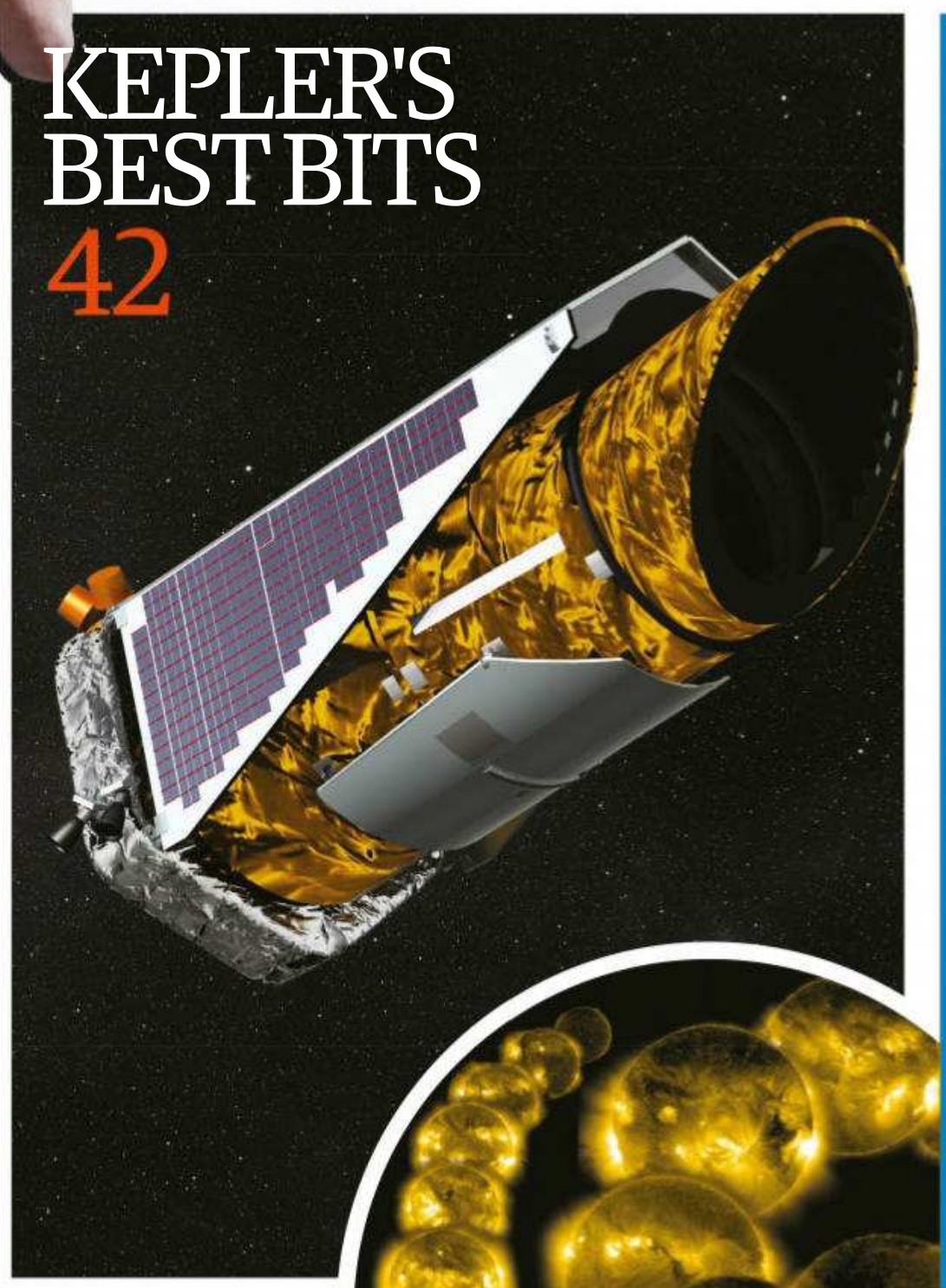


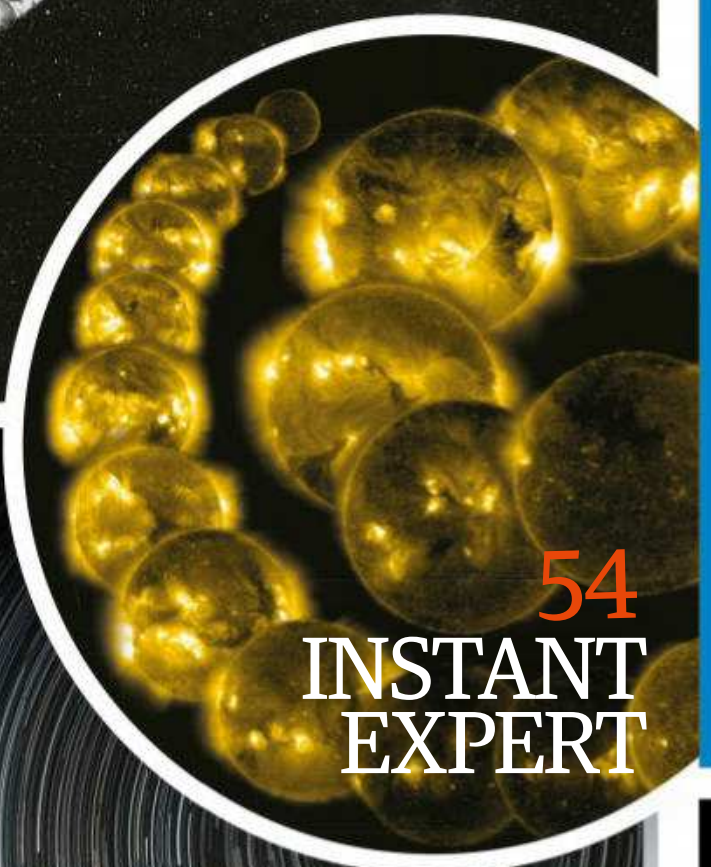


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Your complete guide to the night sky

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The southern sky at La Silla

It's a long road to the European Southern Observatory (ESO)'s La Silla Observatory in the Atacama Desert in northern Chile: it needs to be situated in a place not tainted by light pollution and high enough to minimise air interference. Upon arrival the most beautiful landscape is there to greet visitors.

Sitting underneath the beautiful southern sky, containing the Milky Way disc, is the Swiss 1.2-metre (four-foot) Leonhard Euler Telescope. Off to the far right is the Swedish-ESO Submillimetre Telescope, and sitting strikingly in the centre is ESO's 3.6-metre (12-foot) telescope, which plays host of the famous High Accuracy Radial velocity Planet Searcher (HARPS) instrument.

© ESO

How to punch a hole in a galaxy

Overlaid onto an image taken by the Hubble Space Telescope of the galaxy AM 0644-741 is X-ray data taken by NASA's Chandra X-ray Observatory. Viewing the region's X-ray emissions has revealed a hidden ring of black holes and neutron stars, represented by purple smudges.

Although this ring can't rule them all, the darkness has bound them. Astronomers theorise that this ring of dense stellar objects rose from an ancient collision between AM 0644-741 and a fellow galaxy. The gravitational attraction endured the formation of extremely massive stars, from which these dense objects can be formed.

© NASA

The Sun, Our Living Star

The most massive object in our Solar System, the Sun, has its influence felt at the furthest reaches of the solar neighbourhood. On Earth, its influence is vital for creating and maintaining life as we know it, which is why ESO have announced a collection of free, high-quality planetarium material titled *The Sun, Our Living Star*.

This unusual face of the Sun reveals the movement of highly energetic particles coursing around its outer atmosphere and violent expulsions of material, that are visible on the right of this image.

ESO

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Another 'lunar' step closer for Orion

Deep-space exploration to the Moon and beyond has taken a successful step forward as NASA engineers have completed the final tests of the Orion parachute system. Eight tests were conducted at the United States' Yuma Proving Ground in Arizona.

There are a lot of happy NASA employees after these tests as they showed that the Orion module can deploy 11 parachutes within about ten minutes of falling through the Earth's atmosphere. This brought the speed down from 480 kilometres (300 miles) per hour to a steady 32 kilometres (20 miles) per hour as it splashed down in the Pacific Ocean.

© NASA

Underwater robots benefitting deep-space missions

NASA is known for training its astronauts in underwater conditions as it provides a environment similar to the restricted movement an astronaut would experience in space. Now NASA are taking to the deep Pacific Ocean in order to improve the search for life in deep-space missions.

The Systematic Underwater Biogeochemical Science and Exploration Analog, or SUBSEA, project is a collaborative effort between NASA, National Oceanic and Atmospheric Administration, the Ocean Exploration Trust and more. This project will drop two robotic explorers off the coast of Hawaii to explore the deep-sea environment near a volcano, which scientists believe will be similar to ocean worlds such as Saturn's moon Enceladus.

© Ocean Exploration Trust/Nautilus Live

The Carina Nebula shines right back

Much like a pirate who has just opened up some long-lost treasure, astronomers were delighted to find a flurry of cosmic gems shimmering back at them after taking this image of the Carina Nebula (NGC 3372) in infrared light. The image shows a multitude of glowing stars with a fine contrast of stellar colours, complemented by illuminated clouds of gas.

The most massive stars shown in this image are emitting intense waves of radiation, which are in turn making the surrounding clouds glow. As for the darker clouds, within these dusty nests stars are in the process of being formed, but don't yet have the power to shine as intensely.

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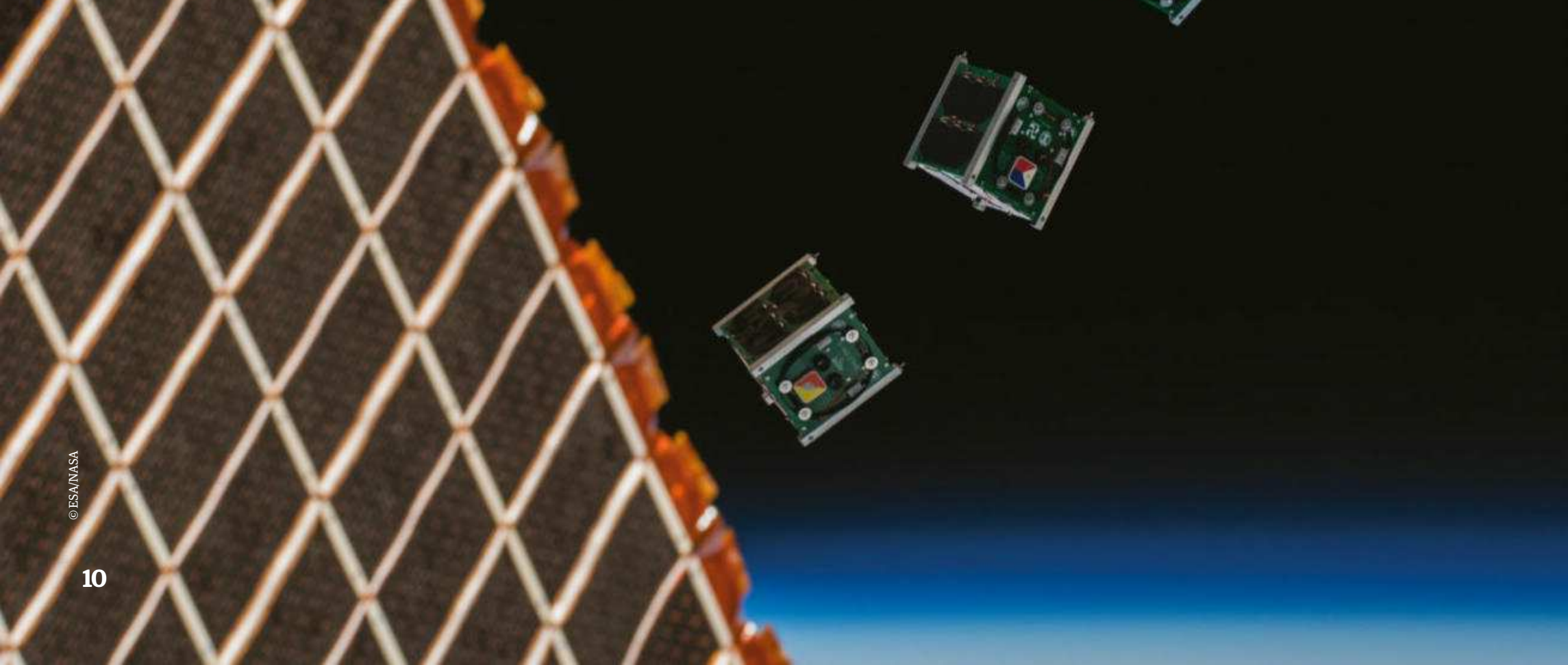
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Snapping a galaxy in some spare time

This spectacular image is of the spiral galaxy NGC 3981 which lies approximately 65 million light years away from Earth in the constellation of Crater, and it provided an excellent pastime for the European Southern Observatory (ESO)'s Very Large Telescope.

One night in May 2018 in Chile, the weather proved unsuitable for scientific observations, but instead of sitting idle and doing nothing scientists captured this galactic beauty as part of ESO's Cosmic Gem Programme. This outreach programme will benefit greatly from having this galactic snapshot which presents all the appealing characteristics a galaxy has to offer.

© ESO



© ESA/NASA

Dune fields on Mars

The Martian surface is a curious one; many features on it are mirrored on Earth, allowing astronomers to draw conclusions about its history based on Earth-based observations. In this instance, NASA's Mars Reconnaissance Orbiter has pictured a region known as the Coprates Chasma and its dune fields.

These regions are more specifically known as 'wall dune fields' as they are located along canyon wall slopes. They occur due to the downward transport of dune sediment from airflow erosion, amongst other processes. Dune fields such as these tell astronomers a lot about the planet's processes of which make short work of shaping these features.

© NASA/JPL-Caltech

Collaborative effort for CubeSats

Now Bhutan, South Asia, can be added to the ever-growing list of countries to have a satellite in space, as the three miniature CubeSats were recently launched from the International Space Station (ISS). Along with Malaysia and the Philippines, this trio of satellites represents the benefits of international cooperation and the desire to explore the harshest frontier.

Originally the ISS was built as a collaborative effort between the United States, Canada, Japan, Russia and numerous European countries. Now, 20 years since its launch, the ISS has furthered the effort by offering the chance for other less-fortunate countries to have a taste of space exploration and reap its benefits.

Multi-wavelength Deep Field

Almost all astronomers will be aware of the Hubble Deep Field image from 1995 and the Hubble Ultra Deep Field images taken in 1995 and 2004 respectively. Hubble took enormous amounts of time collecting light from the deepest regions of the universe to reveal a truly remarkable spectacle.

What is less commonly known is that Hubble was also part of The Great Observatories Origins Deep Survey (GOODS) programme. This initiative utilised other space observatories such as NASA's Spitzer and Chandra and ESA's Herschel and XMM-Newton to provide this magnificent, multi-wavelength perspective of the expanding universe.

© ESA/Hubble & NASA



Yusaku Maezawa has set up a website – **dearmoon.earth** – which he will use to update his voyage to the Moon

SpaceX selects billionaire for mission to the Moon

A Japanese entrepreneur is set to become the first passenger on board Elon Musk's history-making rocket

SpaceX is set to send a Japanese billionaire and eight artists on a pioneering 'private passenger' trip around the Moon in 2023. The rocket company's founder, Elon Musk, announced that a 42-year-old entrepreneur, Yusaku Maezawa, had paid for the places in the hope of completing a week-long voyage, although the exact sums involved have not been revealed.

The history-making trip will be made on board SpaceX's Big Falcon Rocket (BFR) and it is likely to be the first time humans will have visited the Moon since the last Apollo mission in 1972. That voyage was manned by astronauts Gene Cernan, Harrison Schmitt and Ron Evans who carried out scientific work, but the forthcoming journey will be entirely recreational.

"Finally I can tell you that I choose to go to the Moon," Maezawa said during the announcement at SpaceX headquarters near Los Angeles. "At the same time, I did not want to have such a fantastic experience by myself. I want to share this experience with as many people as possible."

Maezawa will become the first non-American to orbit the Moon, and he wants the artists who accompany him to "see the Moon up close and the Earth in full view, and create works that reflect their experience." There was also a suggestion that Musk may accompany the travellers; "Maybe we'll both be on it," Musk said. In any case, it is thought the party will have spent anything in the region of $150 million for the trip.

Before it can get off the ground, however, the BFR will need to be tested. The fully reusable launch vehicle and spacecraft system remains under development. It will include the most powerful rocket ever built and capacity for 100 passengers. In September 2018 Musk showcased a redesign that had added wings and canard fins. Coming in at an overall height of 118 metres (287 feet) and nine metres (30 feet) diameter, it has cost around $5 billion dollars so far.

Maezawa is the founder of the online fashion retail website Zozotown, which has grown to become Japan's largest since it launched in 2004. Forbes estimates his net worth at $3.6 billion dollars and he is the 14th-richest person in Japan. A keen art collector, he told those who attended the announcement: "I wish to create amazing works of art for humankind."

> "I want to share this experience with as many people as possible"

© SpaceX

Drill hole was not made by crew members, says NASA

The space agency hits out at Russian suggestion ISS crew could have been to blame for a breach in the Soyuz spacecraft

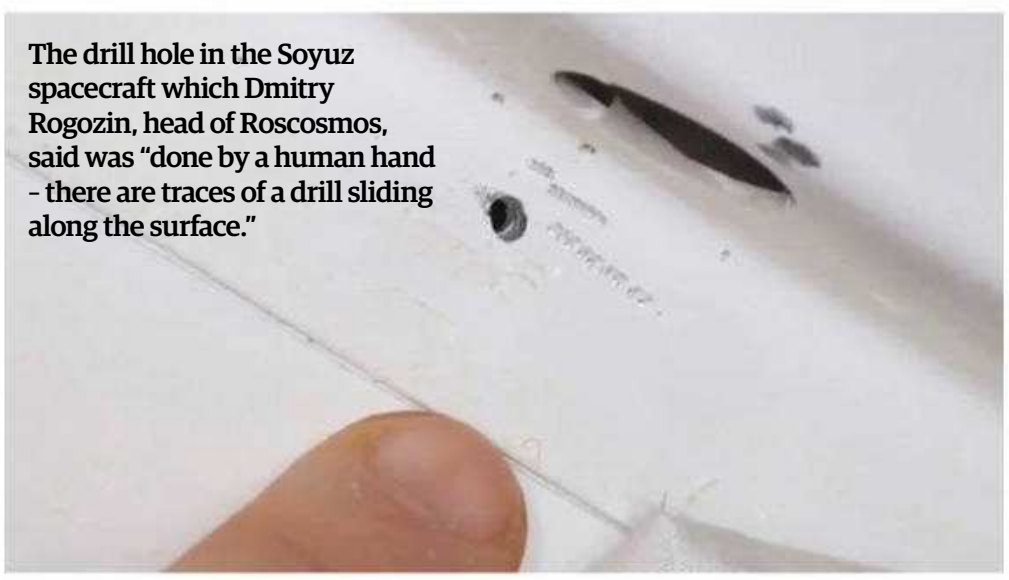
A NASA astronaut has blasted a Russian official's suggestion that crew members of Expedition 56 caused an air leak on the International Space Station. The expedition's commander, Drew Feustal, spoke out after Dmitry Rogozin, the head of Russia's federal space agency, said a hole found in the wall of the docked Soyuz spacecraft had been made by a drill.

"I can unequivocally say that the crew had nothing do with this," Feustel told ABC News following a Russian-led investigation. "I think it's absolutely a shame and somewhat embarrassing that anybody is wasting any time talking about something that the crew was involved in."

Rogozin, who until recently was Deputy Prime Minister of Russia, had claimed that the hole – which caused a small drop in pressure on 29 August – was due to a "faltering hand". He had gone on to say that it was either done intentionally or by accident "either on Earth or in space", raising the suspicion that one of the crew was responsible.

Given there were three NASA astronauts, a European and two Russian cosmonauts on board, the finger was seen to be pointing at the Americans. The crew located the leak to a two-millimetre hole on 30 August and quickly used gauze and epoxy to patch it. Feustel said the crew had followed emergency procedures and reacted appropriately, but Rogozin pointed to marks nearby which suggested a drill had slipped.

"I hope the teams and the investigators on the ground are going to do proper due diligence in trying to solve this problem, because the implications are enormous to the whole space program," said Feustel.



The drill hole in the Soyuz spacecraft which Dmitry Rogozin, head of Roscosmos, said was "done by a human hand – there are traces of a drill sliding along the surface."

© NASA

The Solar System was rearranged earlier than thought

Studies of the only large binary asteroids close to Jupiter indicate early planetary upheaval

An unusual pair of asteroids appear to indicate an early planetary shake-up in our Solar System, according to an American planetary scientist. David Nesvorny, the lead scientist of a new study at the Southwest Research Institute in Texas, has been looking closely at the binary asteroid Patroclus-Menoetius, which is made up of two rocks that orbit around each other as they circle the Sun.

Residing in a cluster of space rocks known as the Trojan asteroids – one of which orbits ahead of Jupiter and the other which orbits behind – Nesvorny says they were forced from their previous position in what became the Kuiper Belt. This, he adds, happened about 100 million years after the Solar System formed – much earlier than had been thought before, with Uranus and Neptune kicking the objects inward as they themselves were pushed outwards.

"The Trojans were likely captured during a dramatic period of dynamic instability when a skirmish between the Solar System's giant planets – Jupiter, Saturn, Uranus and Neptune – occurred," Nesvorny explains. Since the binary asteroid survived intact as it became trapped around Jupiter, he says the planetary rearrangement of the Solar System could not have occurred hundreds of millions of years later as other models have shown because the binary would have broken up in collisions with other space rocks before it arrived within the group.

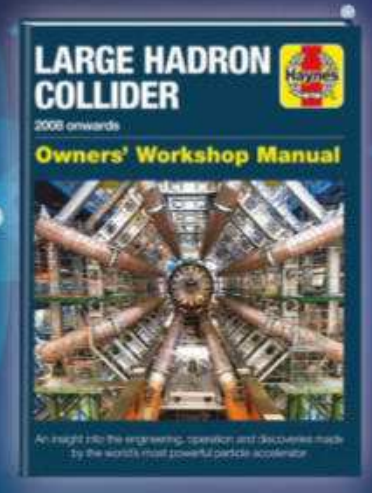


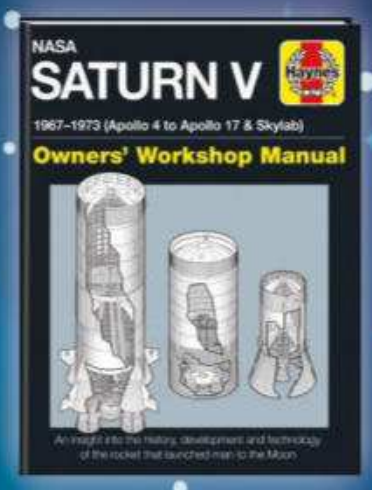
Artist's impression of the binary asteroid Patroclus-Menoetius, which points to a shake-up happening in the first 100 million years of the Solar System

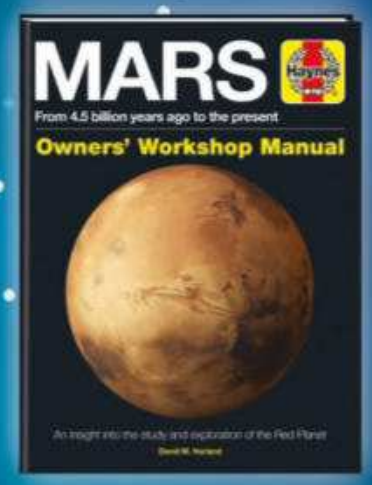
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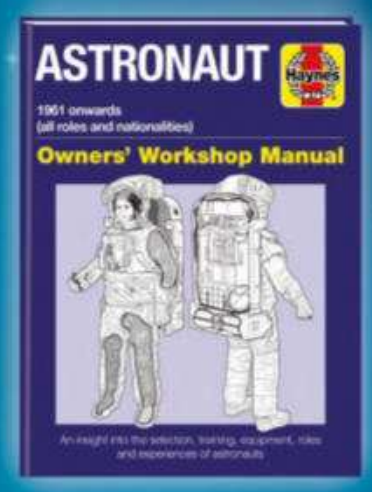
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India unveils new spacesuit

ISRO's space agency moves a step closer to sending astronauts into space from its own soil by unveiling new aeronautical attire

The future is orange, it would seem – at least if this new spacesuit designed for the Indian Space Research Organisation is anything to go by. The space agency is aiming to be only the fourth to send astronauts into space, joining the US, Russia and China, and they've decided to stick with the colour International Orange that other agencies have used for decades because it's highly visible against other landscapes (white, incidentally, is reserved for Extravehicular Activities).

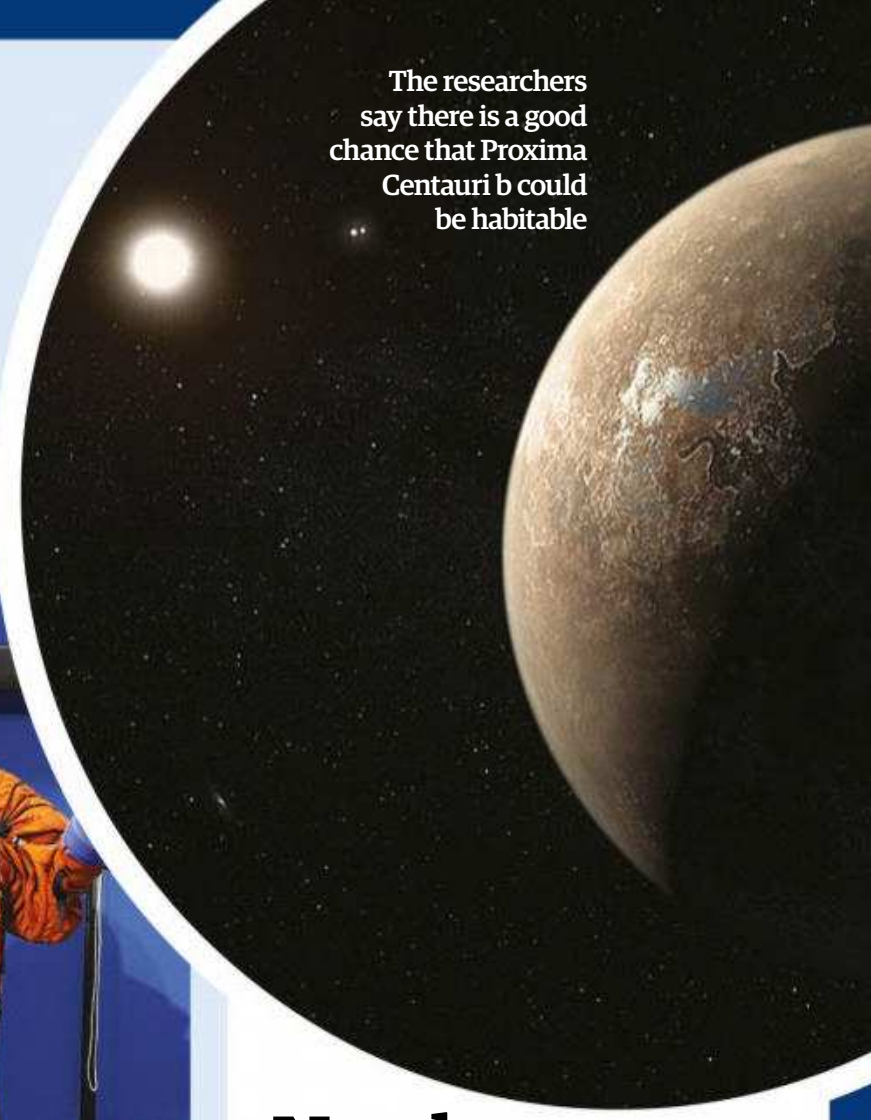
Unveiled a month after India's Prime Minister Narendra Modi said the country would send a crew of humans to space by 2022 – coinciding with the 75th anniversary of the country's independence – the space suit is equipped with a capacity of one oxygen cylinder that can hold enough oxygen for an hour. It is made up of four layers of special lightweight bio-compatible technical textiles with advanced fabrication and joining techniques. According to reports, two space suits have been developed so far and a third is underway.

They are being worked on at the Vikram Sarabhai Space Centre and each weighs less than five kilograms (11 pounds). They'll be worn on the historic journey with the Indian tricolour flag proudly displayed and with the astronauts most likely to be called either gaganauts or vyomanauts since 'gaga' and 'vyom' are Hindi and Sanskrit for 'sky'. The agency's voyage into space for a five-to-seven-day mission will also mark 38 years since Rakesh Sharma became the first and only Indian citizen to travel in space. He flew aboard Soyuz T-11 which was operated by the Soviet Union.



The prototype space suit was put on display at the Space Applications Center in Ahmedabad, India, in August

© Pallava Bagla / Getty images



The researchers say there is a good chance that Proxima Centauri b could be habitable

Nearby exoplanet could host life

Astronomers searching for a habitable planet believe Proxima Centauri b's likelihood of water makes it a prime candidate

Computer models used in the study of Earth-based climate change have shown that the exoplanet Proxima Centauri b may be capable of sustaining life. Research detailed in the journal *Astrobiology* shows the possibility of Earth's "next-door neighbour" being a potential habitable home. Indeed, in running 18 simulations the scientists found Proxima Centauri b had – in most cases – a form of salt or freshwater liquid ocean on its surface.

Even though the exoplanet is thought to be so close to its star that it is tidally locked – the effect of which is to have one side facing the star at all times – the simulations showed that a dynamic, circulating ocean could transfer heat from one side of the exoplanet to the other, leaving a band of liquid water around the equatorial region.

This differs from a previous paper, published in 2016, which said the side facing the star would be scorched while the other side would be frozen. "The major message from our simulations is that there's a decent chance that the planet would be habitable," says planetary scientist Anthony Del Genio, from New York City's NASA Goddard Institute for Space Studies.

Pluto status challenged once more

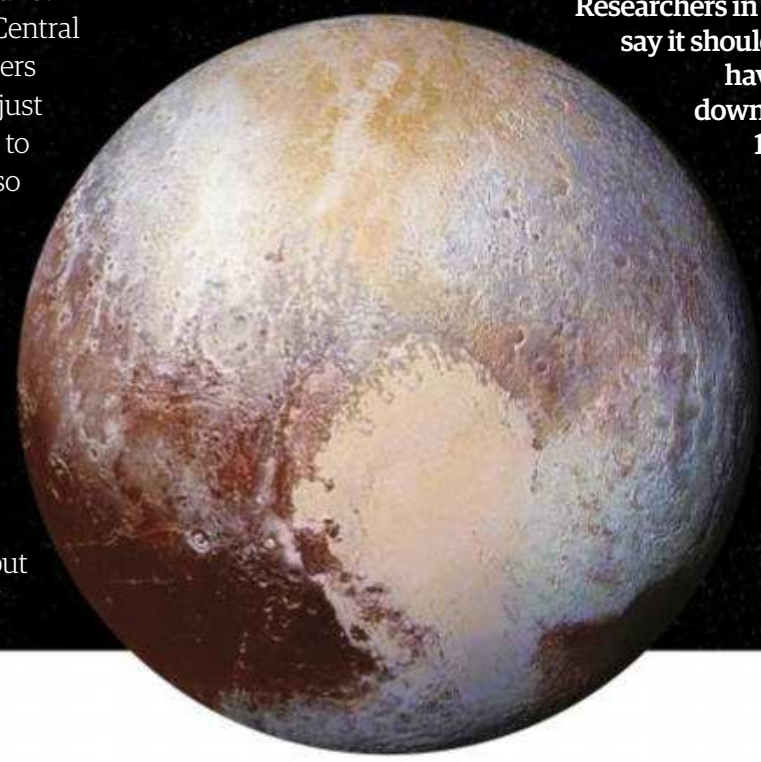
Debate continues over the dwarf planet's stripped status thanks to scientists trawling 200 years of scientific literature

Since 2006, when the International Astronomical Union officially demoted Pluto's status to that of a dwarf planet, debate has raged over whether the IAU's reasoning is correct. Having stated that planets must be in orbit around the Sun and be massive enough to be rounded by their own gravity, Pluto fell foul of a third condition which stated planets must clear the neighbourhood around their orbit. But that could one day change.

In an attempt to help clear up the 'Pluto is a planet' argument, four scientists from the University of Central Florida have pulled out academic astronomy papers dating back to 1802. In doing so they found that just one publication used the clearing-orbit condition to classify planets, and that its reasoning for doing so has since been dispelled.

The rest, they say, showed the standard for classifying planets is not supported by research literature. Indeed, scientist Philip Metzger said moons such as Jupiter's Europa and Saturn's Titan have been referred to as planets by planetary scientists for many decades.

"We now have a list of well over 100 recent examples of planetary scientists using the word planet in a way that violates the IAU definition, but they are doing it because it's functionally useful," says Metzger, who believes the IAU definition to be sloppy. He adds that planets should be classified on the basis of them being large enough that their gravity allows them to become spherical in shape, although Mike Brown of Caltech, who calls himself @plutokiller on Twitter, wrote in response to reports on the finding: "The stupidity never ends."



Is Pluto a planet? Researchers in Florida say it should never have been downgraded 12 years ago

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Aircraft flow by Kurt von Crailsheim, FFA 53, Monthois, France, October 1915.

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Think you understand gravity? Think again. The everyday force is a constant source of questions for physicists - and some are looking to replace the theory

— Reported by Abigail Beall —

GRAVITY

WHY DOESN'T IT MAKE SENSE?

Gravity is everywhere, and you can see the effects everywhere you look. It's the reason the planet orbits around the Sun, the Moon orbits Earth and your feet stay planted firmly on the ground. It's one of the first aspects of physics we encounter at school, for example, with the tale of Newton and his apple falling off his head. Yet we know surprisingly little about this 'invisible force'.

Gravity belongs to a family of four forces that between them can answer pretty much any question along the lines of 'why does that happen?' when it comes to physics. Along with the strong force, the weak force and the electromagnetic force, the gravitational force governs the way everything interacts with each other in the known universe.

Gravity has been a source of wonder for humans since 1687 when Newton realised a force was needed to 'keep the Moon in her Orb'. Because of this long history, it would be understandable to assume gravity is the most well-understood of the forces, but it's not that simple.

Some of the greatest scientists to have lived, notably including Einstein, have dedicated their lives to understanding the force of gravity. Newton described gravity as a force, but Einstein went further, showing gravity to be the result of how mass and energy distort space and time. As a result, we are clued up on how it works on a classical scale in moderate gravitational fields – think of how satellites orbit the Earth, or how planets orbit the Sun, all of which can be described by Newton's equations of motion.

The exception was Mercury's orbit around the Sun, which Newton could not explain. Mercury, being so close to our nearest star, experiences a stronger gravitational field and it took Einstein and his General Theory of Relativity in 1915 to explain how that stronger gravity influences the swift world's path.

What is more, Einstein's theories predict how massive objects like stars distort space-time to the extent that they bend light around them, magnifying it in a process known as gravitational lensing. Predictions Einstein made in equations almost 100 years ago are still being tested in the most extreme gravitational environments that we know of, such as around black holes and binary neutron stars, and those equations are turning out to hold true now. For example, the first evidence showing how the motions of stars orbiting a supermassive black hole are affected in accordance with general relativity was published in August of last year.

But there are a few key problems with gravity that still need to be explained.

"There are many mysteries about gravity" says Paul Sutter, astronomer at Ohio State University.

What causes gravity?

"We think it may be caused by a particle called a graviton. Gravity is the ultimate force of attraction throughout the universe. Everything with mass also has gravity, including stars, planets and even people. The pull of an object's gravity gets stronger as you get closer, and its strength is proportional to the object's mass. Something as big as the Earth has enough gravity to keep us pulled down to its surface, and the Sun has enough gravity to keep the Earth orbiting around it. The mathematics of gravity were first described by Isaac Newton in the 17th century, while Albert Einstein, about 100 years ago, showed how gravitation could be better understood as a warping of space and time."

Dr Robert Hurt, NASA Spitzer Space Center

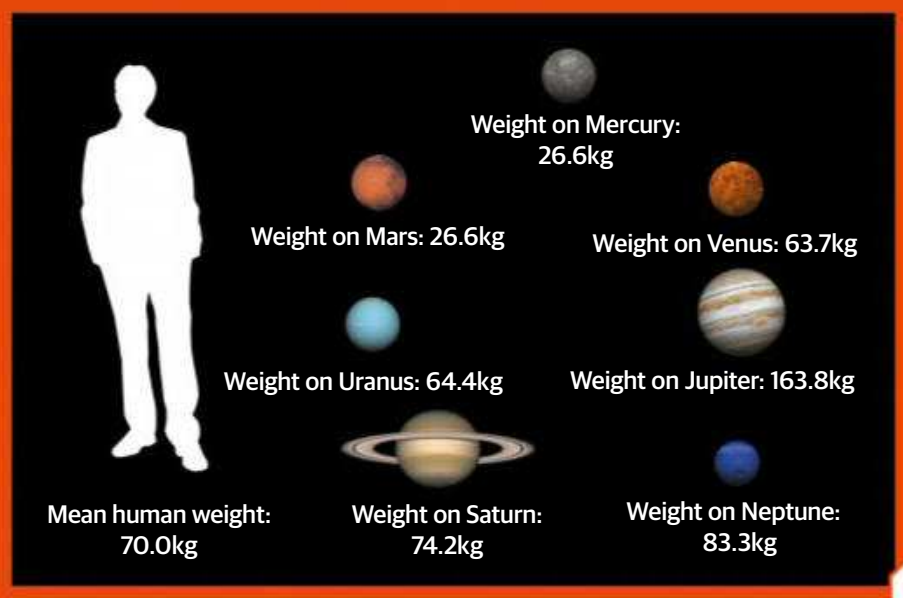
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What exactly is gravity?

It has a lot of effects that we may not even think about

1. It gives us weight

Although your mass – the amount of 'stuff' that you are made of – would remain the same wherever you are in the universe, your weight would vary considerably. Weight is a force determined by gravitational attraction. It's the product of a large body's 'acceleration due to gravity' (g) and its mass. So, for example, if your mass – not weight – was 70kg and Earth's g is 9.81m/s^2, your weight would be 686.7 Newtons.



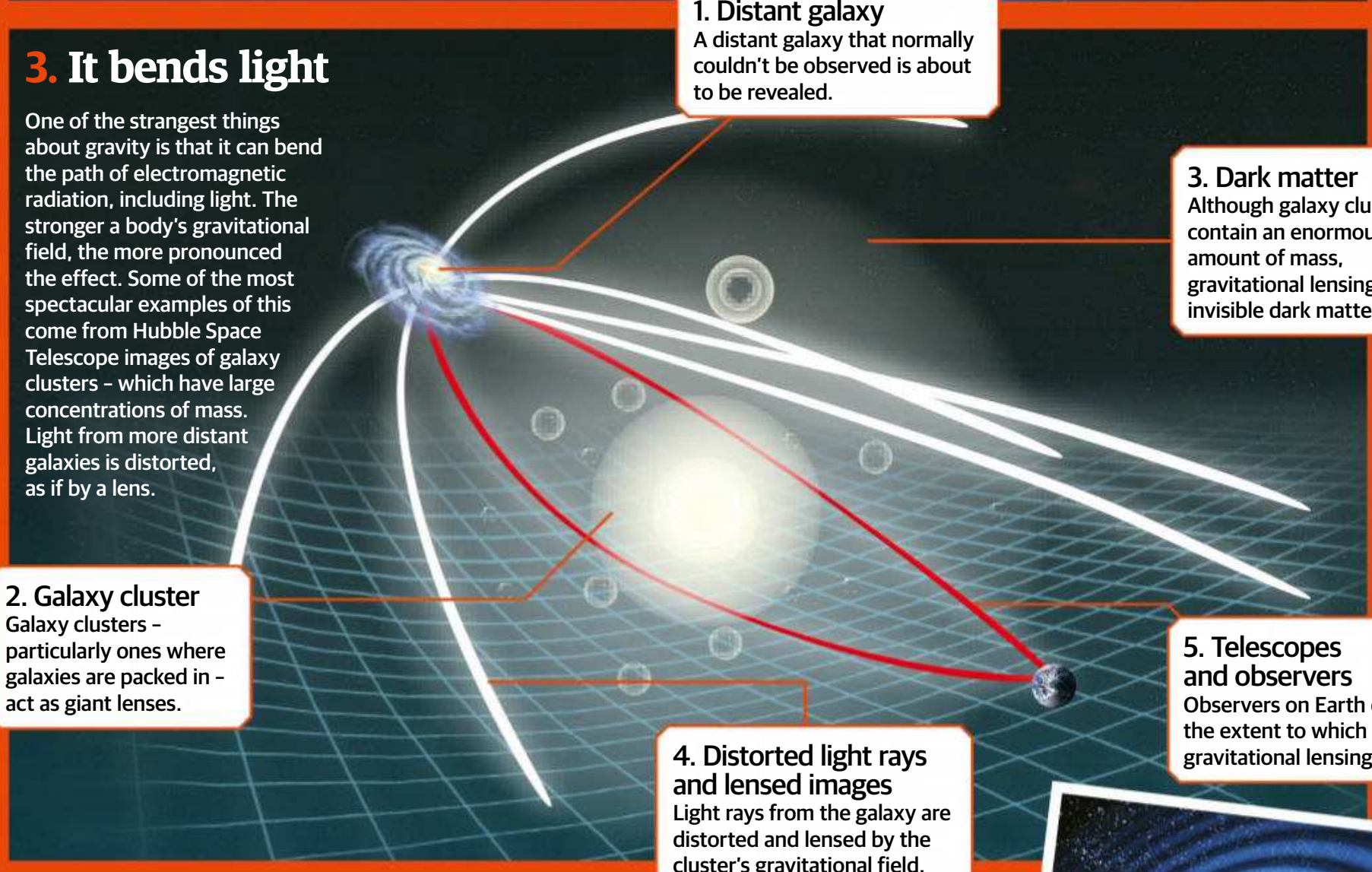
2. It causes objects to gravitate towards each other

Bodies with significant mass can influence one another across thousands of astronomical units, or AU (one AU being the distance between Earth and the Sun). It's no surprise that planets close to the Sun should orbit it in a gravitational 'dance'. What is surprising is that so should a tiny dwarf planet like Sedna, which gets out to 936 AU.



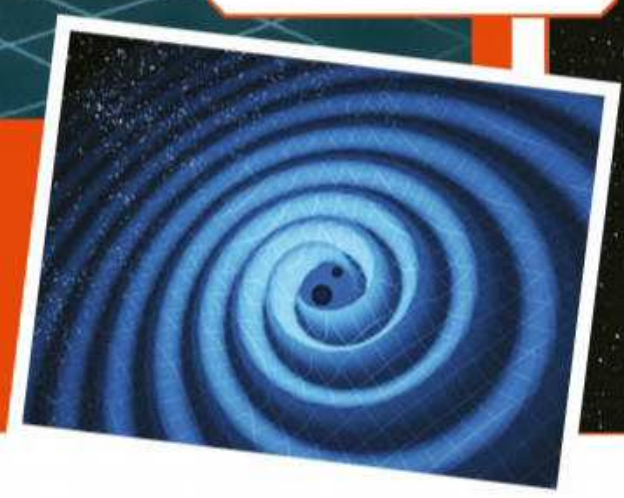
3. It bends light

One of the strangest things about gravity is that it can bend the path of electromagnetic radiation, including light. The stronger a body's gravitational field, the more pronounced the effect. Some of the most spectacular examples of this come from Hubble Space Telescope images of galaxy clusters – which have large concentrations of mass. Light from more distant galaxies is distorted, as if by a lens.



4. It causes ripples in space-time

One of the most extraordinary discoveries of this century was the existence of gravitational waves, or 'ripples' in space-time. These were detected by the Laser Interferometer Gravitational Wave Observatory, operated by Caltech and MIT, in September 2015 and are thought to have come from two colliding black holes 1.3 billion light years away. Although it was thought that gravitational waves could be detected from such an extreme event, no one had any idea when, or if, that would happen.



"For one, why is it so weak? It's far, far weaker than any of the other forces."

Gravity might not feel feeble when you are walking up a steep hill, or falling over. Yet the fact that you can overcome the force of gravity from a mass as large as the Earth's and stand up straight highlights how weak it is, comparatively. Gravity is around 1040 times weaker than the other forces, including the electromagnetic force that holds atoms together. It's even weaker than the 'weak force' that causes radioactive decay. Maybe gravity has been given the wrong name.

There are a multitude of theories as to why gravity is so weak, but no clear leading contender. "I don't think any current options look very promising right now," says Sutter. "We're floundering when it comes to extending our knowledge of physics, and we're only now beginning to design what we hope to be the right kinds of experiments to give us a clue as to what nature is thinking."

However, the answer could lie in solving the problem that not only eluded Einstein, but every physicist since – the unification of gravity, which describes things on very larger scales, with quantum physics, which is famous for describing behaviour on very tiny scales.

If gravity is quantised on the smallest scales, like light is, then it must have a particle that carries its force through quantum fields. For light, this particle is the photon. Gravity's force carrier would be the graviton, but it remains merely hypothetical at this point in time.

Two of the most popular attempts to derive a quantum theory of gravity are String Theory and Loop Quantum Gravity. String Theory proposes that all of matter is made up of tiny vibrating strings, and that one of these vibrational states represents that of a graviton. String Theory also requires extra dimensions beyond the four of space and time that we are familiar with, and some scenarios suggest that the gravity we experience is weak because it is leaking in to our four-dimensional space-time from another dimension that is curled up so tight that we can't otherwise detect it.

Meanwhile, Loop Quantum Gravity tackles the problem from a different angle by saying that space itself is quantised - that is, it can be broken down into the smallest possible pieces called quantum loops of gravity. However, it's still a fairly undeveloped theory, since it does not predict the graviton and it hasn't been shown that it is related to general relativity.

Like electromagnetism, gravity has an infinite range, which means it only gets weaker and weaker the further the two objects are apart, and never goes completely to zero. This is unlike the weak and strong forces, which only work within a specific range. This itself is not a problem when it comes to understanding gravity, but it does make gravity a strong driver of the universe around us.

Gravity is an attractive force only, and because of this it cannot be cancelled out. This

"Einstein threw a spanner in the works when he described gravity as not a force, but a consequence of the structure of space-time"

Where can we find gravity?

From the phone in your hand to the stars in the sky, gravity is everywhere

Standing on Earth
The reason you do not float up into space is because of the force of gravity between the planet and your body.

Being used by your phone
Your phone has a tiny device called an accelerometer that uses gravity to work out which way the phone is orientated.

In distant galaxies
Every galaxy in the universe is bound together by the force of gravity, caused by the attraction of all its stars and planets.

In the Solar System
Each planet that orbits our Sun is driven by the force of gravity attracting it to our own personal star.

Gravitational lensing has been used to map the distribution of mass around stars, galaxies and clusters of galaxies

© NASA/ESA; LIGO



Gravity is crucial for life on Earth; without it we would not even have a planet

makes it very different to electromagnetism, which can attract and repel. The fact it is only attractive means gravity permeates across the vast distances in the universe with nothing getting in the way. But this is also another reason it makes no sense, according to some scientists.

Martin Tajmar, Professor of Physics at the Technical University Dresden, in Germany, says the strangest thing about gravity is "that there is only positive mass around us with no negative counterpart as in electromagnetism".

If an electromagnetic force is attracting an object, applying an opposite force would balance the original out, meaning the net force on the object would be zero. In what would potentially be the equivalent of this phenomenon but for gravity, Tajmar is looking into ways to 'counter' gravity, an 'anti-gravity' of sorts. He hopes come up with an opposite kind of force that would balance the gravitational pull of an object.

The idea of countering gravity is not only important for making gravity behave like all the other forces. It may have practical applications too. "It would be a game-changing technology like the use of electromagnetism that created the modern world" says Tajmar. "Perhaps, it could open up new ways for space travel too."

But in order to come up with a way to counter gravity, we need to go beyond the theories we currently have.

"Together with my students, I'm looking into theories that predict deviations from our current understanding of gravity" he says. "We are performing experiments to test and verify those very concepts."

For an alternative theory of gravity to be taken seriously, it must be possible to reduce it to general relativity in certain scenarios. Because of this, it is necessary to test the limits of the general relativity to see where it deviates from reality and into the territory of a completely new theory.

Some of these boundaries involve strange links between gravity and other phenomena in physics, like superconductivity. In 2003, Tajmar wrote a paper proposing gravitational effects could be responsible for a difference between the measured mass of pairs of electrons at low temperatures, found in superconductors, compared to the theoretical value. This theory is known to physicists as gravitomagnetism.

"Gravitomagnetism is an approximation to Einstein's theory of general relativity for low velocities in flat space-time" says Tajmar. "It allows us to easily illustrate the effect of space-time 'frame-dragging', for example by the rotating Earth."

Frame-dragging occurs when a massive rotating object drags nearby space-time – and any objects, such as satellites, in that space-time – around with it. In the theory of gravitomagnetism, when the Earth rotates it generates a field similar to the magnetic field generated by a rotating charge. This, in turn, affects the motion of masses similar to the way electrons are deflected if they move at right angle to a magnetic field.

This has been measured, says Tajmar. "Satellites in polar orbit around the Earth are slightly deflected by the rotating Earth in line with Einstein's theory," says Tajmar. "However, the effect [of this frame-dragging] is so small that there are no practical applications so far." There is much more research needed before it can be used as a way to start countering gravity, it seems, or even explaining why gravity only attracts and does not repel.

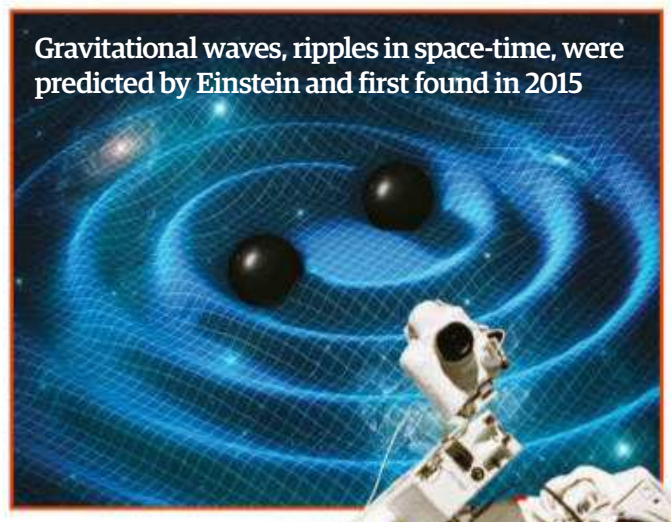
Gravity is especially important when it comes to the structure of the universe. It is responsible for the formation and evolution of galaxies and black holes and, it also acts against the expansion of the universe, trying to slow it down in the face of dark energy, which is accelerating the expansion. Whether gravity or dark energy wins will decide the fate of the cosmos.

Gravitational lenses are a pretty handy tool for measuring the structure and distribution of matter in the universe. The more mass there is in a star, or a galaxy, or a cluster of galaxies, the greater the space-time distortion and the more powerful the gravitational lens. Therefore, the mass, and the distribution of that mass, can be calculated based on the amount of lensing. Yet when astronomers look at gravitational lenses formed by huge galaxy

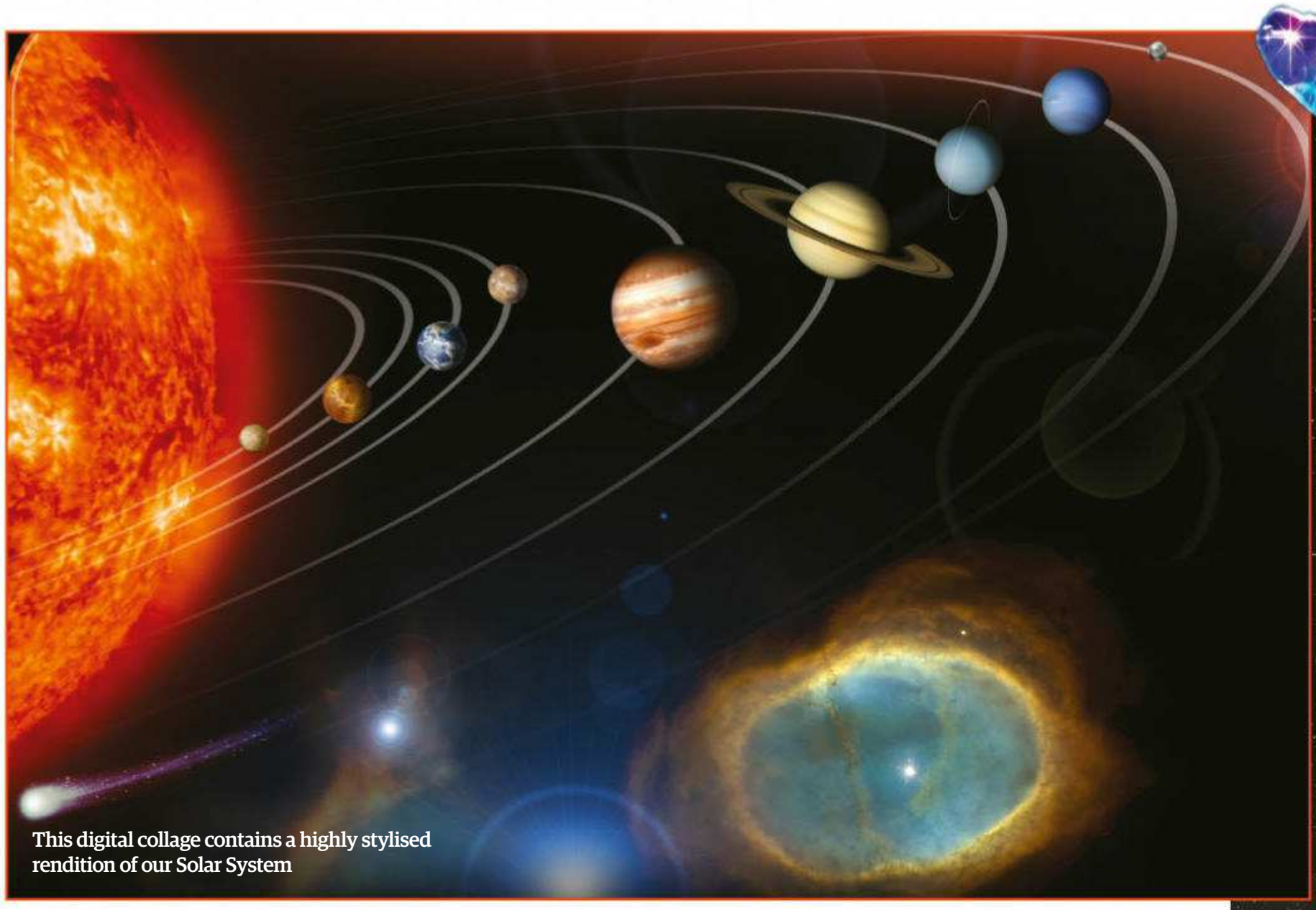
"Gravity is responsible for the structure of galaxies and black holes and slowing down the expansion of the universe"



The attraction of gravity holds together huge galaxies like this one, with its bright blue gas at the centre



Gravitational waves, ripples in space-time, were predicted by Einstein and first found in 2015



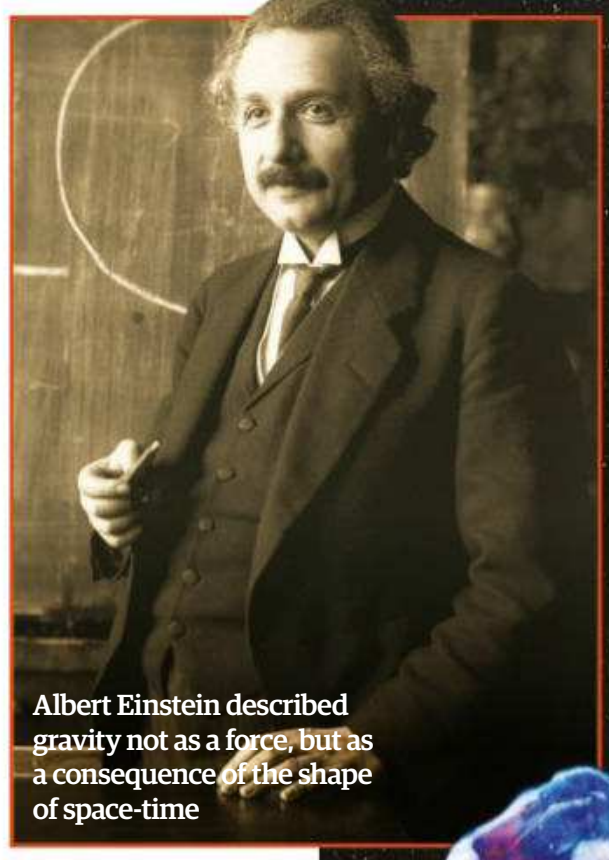
This digital collage contains a highly stylised rendition of our Solar System

clusters, the find that the lensing effect is greater than the mass of the visible galaxies can account for. The implication is that there is some unseen matter - dark matter - that is providing the extra gravity for the lenses. We also see the influence of this extra gravity in the motions of the galaxies on the outskirts of clusters, and stars on the edges of galaxies, which are moving faster than they should be based on the amount of visible matter.

What if, rather than there being dark matter to provide extra gravity, it is gravity itself, or rather our understanding of it, that is wrong? This is the theory put forward by Israeli scientist Mordehai Milgrom in 1983. He called it Modified Newtonian Dynamics, or MOND for short, and it argues that in very low acceleration environments, such as those experienced on the outskirts of galaxies and galaxy cluster, gravity does not follow the traditional theories set out by Newton and Einstein.

Practitioners of MOND are few and far between, since dark matter is by far the most popular theory, but the level of popularity doesn't necessarily dictate that a theory is correct or not. MOND has had some successes, particularly in explaining the rotation of stars around galaxies, but efforts to develop a cosmological theory of MOND, in which it co-exists in the Big Bang and Inflation theories, have so far failed. Nor does MOND have a theoretical framework from which it can be derived, leaving many scientists sceptical about MOND. However, the theory of dark matter has its own problems: nobody knows what dark matter is made of, and searches for dark matter have so far drawn a blank.

MOND does not seek to replace Newton and Einstein's theories, but to complement them, since they operate in stronger gravitational fields to MOND. At the moment, the General Theory of Relativity is our best explanation for gravity, but we know it is not the final answer. For now quantum gravity remains mysterious, but whoever can solve that puzzle which links the gravity of the very large to the gravity of the very small could change physics and our understanding of gravity forever.



Albert Einstein described gravity not as a force, but as a consequence of the shape of space-time

Five things that don't make sense about gravity

It is really weak
Although it can never reduce to zero, gravity is around 10^{40} times weaker than the electromagnetic force that holds atoms together, and no one really knows why.

We have no theory for quantum gravity
Currently, when trying to describe gravity on the tiniest scales, if we try to tie gravity into quantum mechanics, the equations just don't add up.

Gravity can only attract objects
Unlike the other forces, such as electromagnetism, gravity only works in one direction. Objects can only be attracted through gravity, not repelled.

We can't counter gravity
Because gravity is only an attractive force, we have no way of overcoming it. This is a problem for people who want to travel large distances in space.

Not everyone agrees what it really is
Some call gravity a force, but others, like Einstein, say it is not a force. Instead, it is simply a consequence of the shape of space-time.

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15 YEARS OF THE SPITZER SPACE TELESCOPE

This year, one quarter of the Great Observatories has reached a truly outstanding milestone

A mission originally planned for just two-and-a-half years in space is now celebrating its 15th anniversary; a remarkable achievement for NASA's Spitzer Space Telescope. Launched on the 25 August 2003 into a solar orbit, this telescope has been using its infrared-sensitive equipment to reveal the hidden gems of the cosmos.

This space telescope was the fourth and final instalment of NASA's Great Observatories program, and it has been able to view the great beyond in a light that is unperceivable to the human eye, revealing marvellous details about our Solar System and beyond. In terms of numbers the spacecraft posts some amazing figures, given its initial 2.5-year primary mission. It has logged over 106,000 hours of observation time and has citations in over 8,000 published papers, and that's not including the countless images produced.

> "Spitzer has been able to view the great beyond in a light that is unperceivable to the human eye"

This journey hasn't been without its troubles though. In July 2009 the spacecraft entered a 'warm phase' as the liquid helium supply, which was keeping the instruments at sub-zero temperatures, had depleted. Only two of the four cameras that make up the esteemed Infrared Array Camera (IRAC) could operate with the same sensitivity as they would in the 'cold phase'.

"In its 15 years of operations, Spitzer has opened our eyes to new ways of viewing the universe," says Paul Hertz, director of the Astrophysics Division at NASA Headquarters in Washington. "Spitzer's discoveries extend from our own planetary backyard, to planets around other stars, to the far reaches of the universe. And by working in collaboration with NASA's other Great Observatories, Spitzer has helped scientists gain a more complete picture of many cosmic phenomena."

Top-five discoveries

1. Finding the most distant galaxy cluster



The galaxy cluster COSMOS-AzTEC3 was discovered and characterised by an assortment of ground- and space-based telescopes, one of which was the Spitzer Space Telescope. This collection of galactic monsters is located approximately 12.6 billion light years away, with scientists looking at this cluster just one billion years after the universe's formation.

With light travelling from such a distant source, the optical light is stretched and shifted into the infrared section of the electromagnetic spectrum. By observing the galaxy cluster in infrared, scientists are able to uncover previously unnoticed information. These results will hopefully fill in the blanks of galactic evolution by observing these early stages.

2. Discovering cosmic 'buckyballs'



'Buckyballs' are football- (soccer-ball) shaped structures of carbon that were first observed in a laboratory over a quarter of a century ago, but eluded cosmic detection until the arrival of Spitzer in 2010.

These structures are named after Buckminster Fuller's geodesic domes and are composed of 60 carbon atoms arranged in a three-dimensional, spherical shape. Spitzer caught these structures erupting from a planetary nebula named Tc 1, indicating that they were the remnants of a star's outer layers that permeated space after a stellar explosion.





The discovered ring stretches far beyond Saturn

3. Spotting Saturn's largest ring

By looking at the Solar System's second-largest planet in infrared, Spitzer revealed a secret ring that had been hidden for generations. This ring starts enclosing the Saturnian system about 6 million kilometres (3.7 million miles) away from the planet's face, and it extends out to 12 million kilometres (7.4 million miles) distant.

Spitzer was able to detect the faint infrared glow of the cool 80 Kelvin (minus 193 Celsius, or minus 316 degrees Fahrenheit) ring, and now scientists believe that Saturn's farthest moon, Phoebe, would be the source of such material.



Spitzer's observations spotted the huge collision about 1,200 light years away

4. Spitzer watches asteroid collision

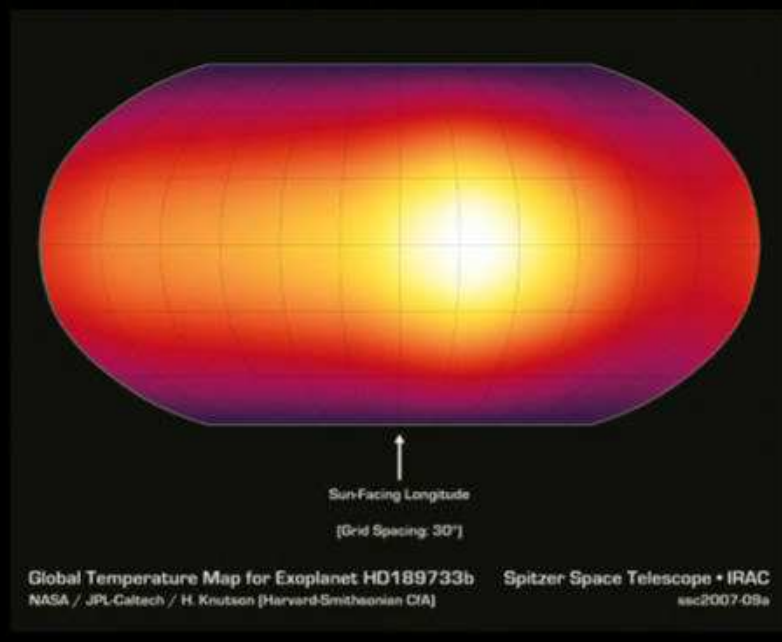
While observing the star system NGC 2547, Spitzer noticed a kick-up of dust that scientists believe to be the collision of two big asteroids. Between August 2012 and January 2013, Spitzer watched over dusty star NGC 2547-ID8, which is about 35 million years old and lies 1,200 light years away in the Vela constellation.

Observations from this rare collision in a different planetary system could provide hints as to how rocky planets form, as astronomers believe our young Solar System was a realm under constant bombardment of asteroids, comets and other planetesimals.

5. First exoplanet weather map

Spitzer was able to tell the temperature of the exoplanet HD 189733b, located roughly 60 light years away. The infrared weather map created revealed a windy planet that is extremely hot, with temperatures reaching 930 degrees Celsius (1,700 degrees Fahrenheit) on its dayside.

This hot Jupiter planet orbits incredibly close to its parent star, causing unusual temperature changes within the planet. Visible-light telescopes are able to detect planets and characterise their size and orbit, however, infrared is much better equipped to reveal its planetary weather.



© NASA/JPL-Caltech

Planet Profile

Venus

Earth's sister planet is a harsh, deadly world, making it an interesting one to observe

'Hell on Earth' is a phrase used by many, but one planet actually matches this idea of a harsh and inhospitable environment; that accolade falls to Venus. The second planet from the Sun is similar in size and density to Earth, with it being only 638 kilometres (396 miles) smaller in diameter and 0.27 grams per cubic centimetre lower in density. These physical dimensions may paint a picture of a world similar to Earth, but that is far from the case. The truth is Venus underwent a different evolution, and its completely different atmosphere has fashioned the hottest surface temperature in the entire Solar System at 465 degrees Celsius (869 degrees Fahrenheit), with atmospheric pressures that are over 90-times that of Earth at sea level.

Venus' atmosphere is composed mainly of the greenhouse gas carbon dioxide, with small amounts of nitrogen and traces of other gases, most notably sulphur dioxide and argon. Comparing this atmosphere to Mars – which is about 100 times thinner than Earth's – again shows that their evolutions took opposite approaches in the sense that one planet lost its atmospheric greenhouse gases, while the other formed a thick atmosphere and, as a result, traps heat in a 'runaway greenhouse effect'. In between these planets – both literally and scientifically – is Earth, as it has moderate amounts of greenhouse gases that allow it to trap enough heat to maintain a habitable surface temperature, perfect for the existence of life.

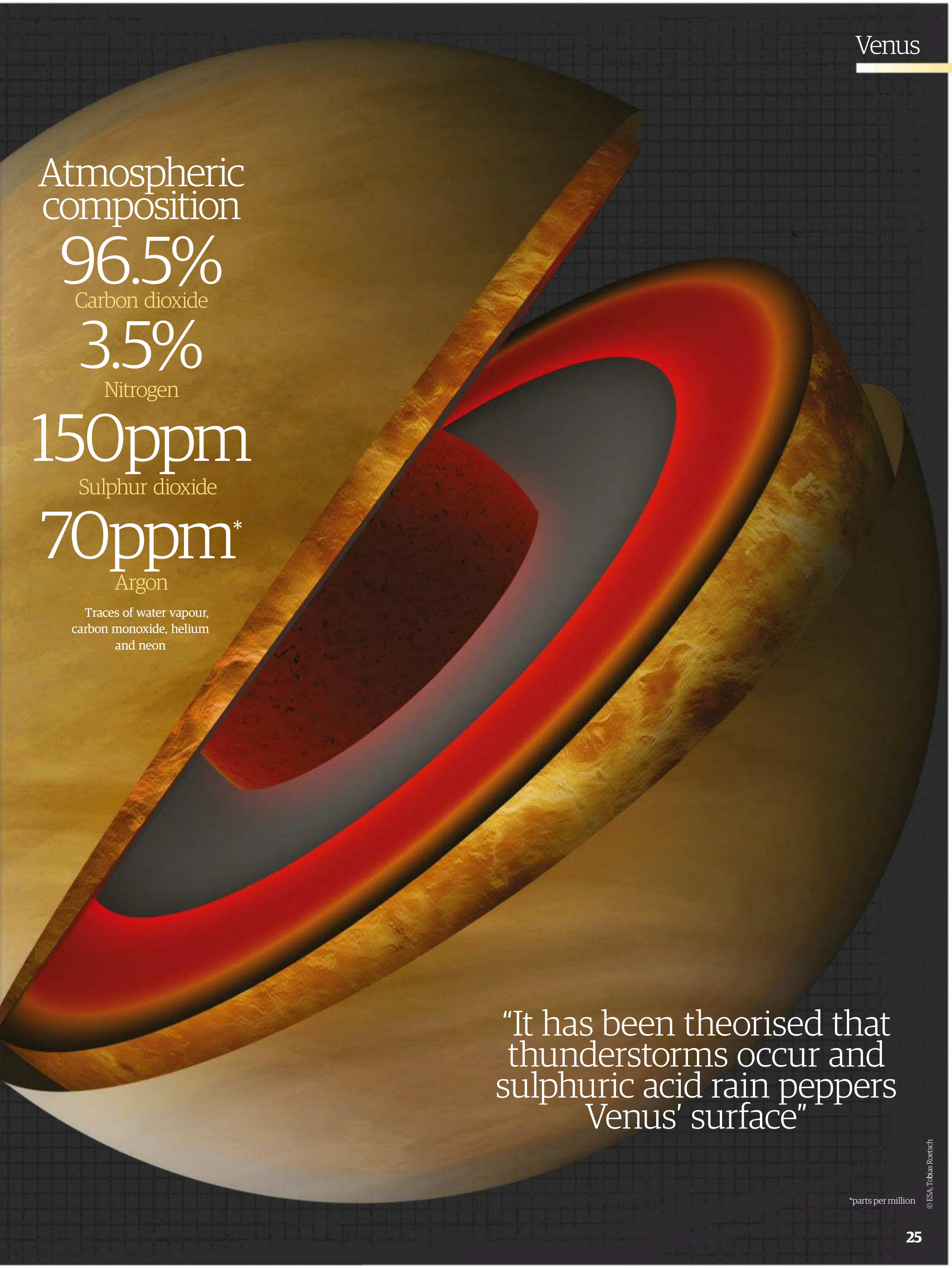
Looking at the surface of Venus has revealed some extremely interesting characteristics that help astronomers and planetary scientists understand the planet's true interior. For instance, volcanoes have been observed on Venus, such as the Idunn Mons volcano in the planet's southern hemisphere rising 2.5 kilometres (1.6 miles) above the surrounding plains. This volcanism is a sign that there is active mantle underneath the rocky surface. This would explain what is powering these volcanoes and also what is replenishing the sulphur dioxide in the atmosphere, creating the acidic clouds too. It has also been theorised that Earth-like thunderstorms occur and sulphuric acid rain peppers Venus' surface, originating from these clouds. Although volcanoes indicate that the planet's surface can be smoothed over by running lava, making it appear younger, there have still been many impact craters spotted on the surface.

Scientists have theoretically scratched the surface and revealed that the interior of Venus is thought to be composed of a partially liquid metallic core and a rocky mantle above that. This theory is based on the calculated mass and density, suggesting the planet is made up mainly of rocks and metals. This remains a theory for now due to observations being much harder because of the planet's thick atmosphere.

Venus hasn't had the same degree of surface visits and orbiter attention as Earth's neighbour on the other side, Mars, due to its lead-melting surface temperature and toxic acid clouds, but it has still been visited by several spacecraft. It has also been influential in providing a 'gravitational slingshot' to missions such as the Cassini-Huygens, MESSENGER and Galileo that took their respective spacecraft to Saturn, Mercury and Jupiter.



A comparison of the four terrestrial planets shows the similarity in size between Earth and Venus



Atmospheric composition

96.5%
Carbon dioxide

3.5%
Nitrogen

150ppm
Sulphur dioxide

70ppm*
Argon

Traces of water vapour, carbon monoxide, helium and neon

"It has been theorised that thunderstorms occur and sulphuric acid rain peppers Venus' surface"

*parts per million

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Venus in the news

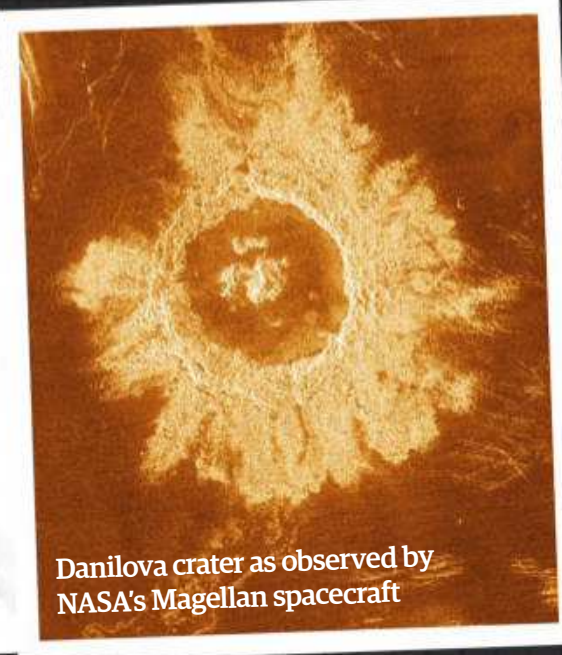
Forming craters on different planets

A recent study has been investigating how meteorites form impact craters, and in particular the feature within the craters called 'rays', on extraterrestrial worlds that include Venus. These rays refer to the long, radial streaks that extend out from the centre of the crater out towards its ring.

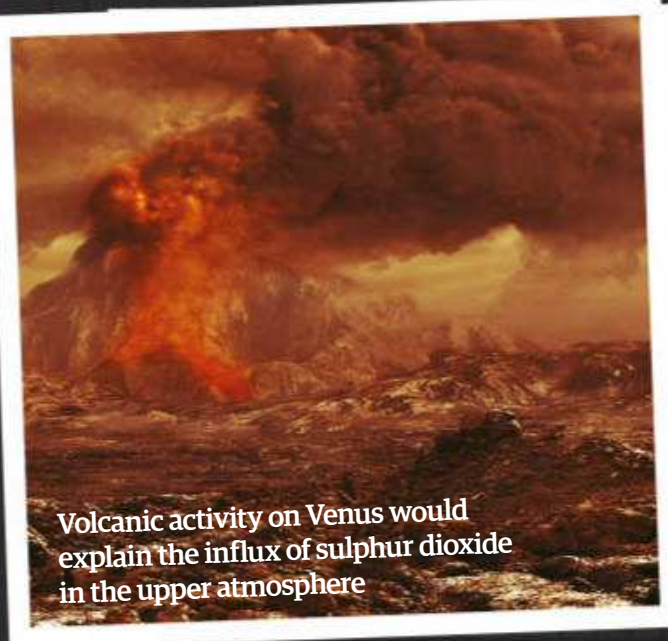
Scientists have been creating analogues to try and understand how these rays form by simply dropping a heavy metal ball onto a sand bed. However, the analogues weren't revealing the origin of the rays. It wasn't until Dr Tapan Sabuwala of the Okinawa Institute of Science and Technology Graduate University, Japan, watched online videos of a ball-drop experiment by secondary school students when he had a eureka moment.

Sabuwala says, "These experiments are popular in science classes. I noticed that some of their experiments were producing crater rays!" But what was the factor creating such features? It was the unevenness of the surface.

Generally, researchers will level out the sand bed during the experiments. However, the messiness of the surface appears to create the rays. There have been many depressions and deformed mountain ranges observed on the surface of Venus. Unfortunately the precise intricacies are still unknown. However, this does give a keen advantage when studying how impact craters are formed on different planets, of which Venus is included.



Danilova crater as observed by NASA's Magellan spacecraft



Volcanic activity on Venus would explain the influx of sulphur dioxide in the upper atmosphere

A piece of Venus on Earth

In a room of the Planetary Spectroscopy Laboratory (PSL) in Berlin, Germany, the German Space Agency (DLR) has opened a new simulation facility that can bring the conditions of Venus to a laboratory. Because Venus' thick outer clouds make observations of the ground extremely rare, this facility allows scientists to analyse rock samples at temperatures of up to 1,000 degrees Celsius (1,830 degrees Fahrenheit).

There have been many space-based observations of Venus from orbiters such as ESA's Venus Express and JAXA's Akatsuki, however, this simulation can now provide emission spectroscopic analysis of rock samples in a range of temperatures, as if actually on the surface of Venus. The results from such experiments will complement the observations taken from the extraterrestrial missions.

"PSL took up this challenge, building on nearly a decade of experience in high-temperature emission spectroscopy in the mid-infrared. After several years of development and extensive testing, PSL is now in routine operation for Venus-analogue emissivity measurements from 0.7 to 1.5 micrometres over the whole Venus surface temperature range," says Jörn Helbert of PSL, who led the development of the new facility.

Explaining Venus' weird rotation rate

By combining observational data with the theoretical work of three researchers from the University of California, Los Angeles (UCLA) in the United States, and Sorbonne Universités in France, a new theory has been proposed to explain the varied rotation rate of Venus.

It is common knowledge that it takes Venus 243 Earth days to complete one spin, but with exact measurements made by previous Venus exploration missions, this time varies by an average of seven minutes. Scientists have struggled to explain this deviation, but astronomers have also noticed that the planet's atmosphere orbits considerably quicker, completing one orbit in just four Earth days.

Astronomers decided to take a look at the possibility of surface mountains carving a long-standing 10,000-kilometre (6,000-mile) wave in the thick atmosphere. On Earth these waves dissipate quickly due to rapid air currents, but Venus' atmosphere is much thicker and causes a longer standing effect. "This interplay between the solid planet and atmosphere may explain some of the difference in rotation rates measured by spacecraft over the past 40 years," says the team of researchers led by Dr Thomas Navarro of UCLA.

Simulations of this showed that the mountains can cause a two-minute variation in the planet's spin. Not enough to account for the full seven minutes, but enough to suggest that other physical features can cause this variation.

Scientists have to use data to simulate what the surface of Venus would look like beneath the thick clouds

Exploration of Venus

Humanity has sent spacecraft all over the Solar System, and Venus is no exception. Although it hasn't had the attention of Mars, Venus has still had its share of spies. The first came in 1962 when Venus had its first visitor in the form of NASA's Mariner 2 space probe. This was the first successful spacecraft to another planet, beating the Soviet Union's Venera and Zond projects. However, the Soviets' Venera 7 became the first spacecraft ever to transmit data from the surface of Venus – for a total of 23 minutes. Venera 7 revealed the planet's scorching surface temperatures, crushing atmospheric pressures and a surface wind speed of 2.5 metres per second (nearly 5.6 miles per hour). Over ten years later, Venera 13 became the first lander to transmit colour images from the surface of Venus.

However, there was still so much more to learn about this mysteriously boiling planet. The major space agencies such as NASA, the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA) have all had a peep.

NASA had the Magellan space probe and the Pioneer Venus project, active between the years 1978 and 1994; ESA had its Venus Express orbiter active between 2006 and 2015 and, after a delayed orbital insertion, JAXA eventually placed its Akatsuki orbiter into orbit around Venus in 2015, where it currently remains.

Venus is visited by spacecraft relatively frequently as it is best used as a 'gravitational slingshot', providing a gravitational boost to spacecraft flying towards their next destination. NASA's recently launched Parker Solar Probe is one such spacecraft. However, scientists and engineers are coming up with new and creative ways of exploring other planets, with NASA even awarding a contract to a drone-specialist company, called Black Swift Technologies, to develop a drone that can explore the upper atmosphere of Venus. The main reason behind this is that scientists now think that the most ideal conditions for life as we know it to survive on Venus resides in the cloud tops.



Flying drones on the clouds of Venus is an innovative way of collecting close-up data about our sister planet

Venus facts

x2

ESA/JAXA's BepiColombo mission to Mercury will undergo two flybys of Venus, the first due on 16 October 2020.

243

A day on Venus lasts 243 Earth days, whereas a year on Venus only lasts 224.7 Earth days, oddly making a day longer than a year.

650bce

Observations of Venus can be traced back to Mayan astronomers in 650 BCE, which lead to a highly accurate calendar.



In the top layer of Venus' clouds winds can reach up to 360 kilometres (224 miles) per hour, making them faster than hurricanes on Earth.

11km

Maxwell Montes, the tallest mountain range on Venus, towers up to roughly 11 kilometres (7 miles) above the planet's mean radius.



Akatsuki was supposed to enter Venus' orbit on 6 December 2010. It successfully entered Venus' orbit on 7 December 2015.

Timeline of exploration for Venus

- **Date:** 27 August 1962 **Agency:** NASA **Spacecraft:** Mariner 2
- **Date:** 12 June 1967 **Agency:** USSR **Spacecraft:** Venera 4
- **Date:** 14 June 1967 **Agency:** NASA **Spacecraft:** Mariner 5
- **Date:** 5 & 10 January 1969 **Agency:** USSR **Spacecraft:** Venera 5 & 6
- **Date:** 17 August 1970 **Agency:** USSR **Spacecraft:** Venera 7
- **Date:** 8 & 14 June 1975 **Agency:** USSR **Spacecraft:** Venera 9 & 10
- **Date:** 20 May 1978 **Agency:** NASA **Spacecraft:** Pioneer Venus
- **Date:** 8 August 1978 **Agency:** NASA **Spacecraft:** Pioneer Venus 2
- **Date:** 15 & 21 December 1984 **Agency:** USSR **Spacecraft:** Vega 1 & 2
- **Date:** 4 May 1989 **Agency:** NASA **Spacecraft:** Magellan
- **Date:** 18 October 1989 **Agency:** NASA **Spacecraft:** Galileo
- **Date:** 15 October 1997 **Agency:** NASA/ESA **Spacecraft:** Cassini-Huygens
- **Date:** 3 August 2004 **Agency:** NASA **Spacecraft:** MESSENGER
- **Date:** 9 November 2005 **Agency:** ESA **Spacecraft:** Venus Express
- **Date:** 20 May 2010 **Agency:** JAXA **Spacecraft:** Akatsuki

Key

Flyby Orbiter Lander

© NASA/JPL, ESA; Adrian Mann

NASA SPACE APPS

You can now explore the cosmos from the comfort of your own home - whatever your budget

— Written by Lee Cavendish —

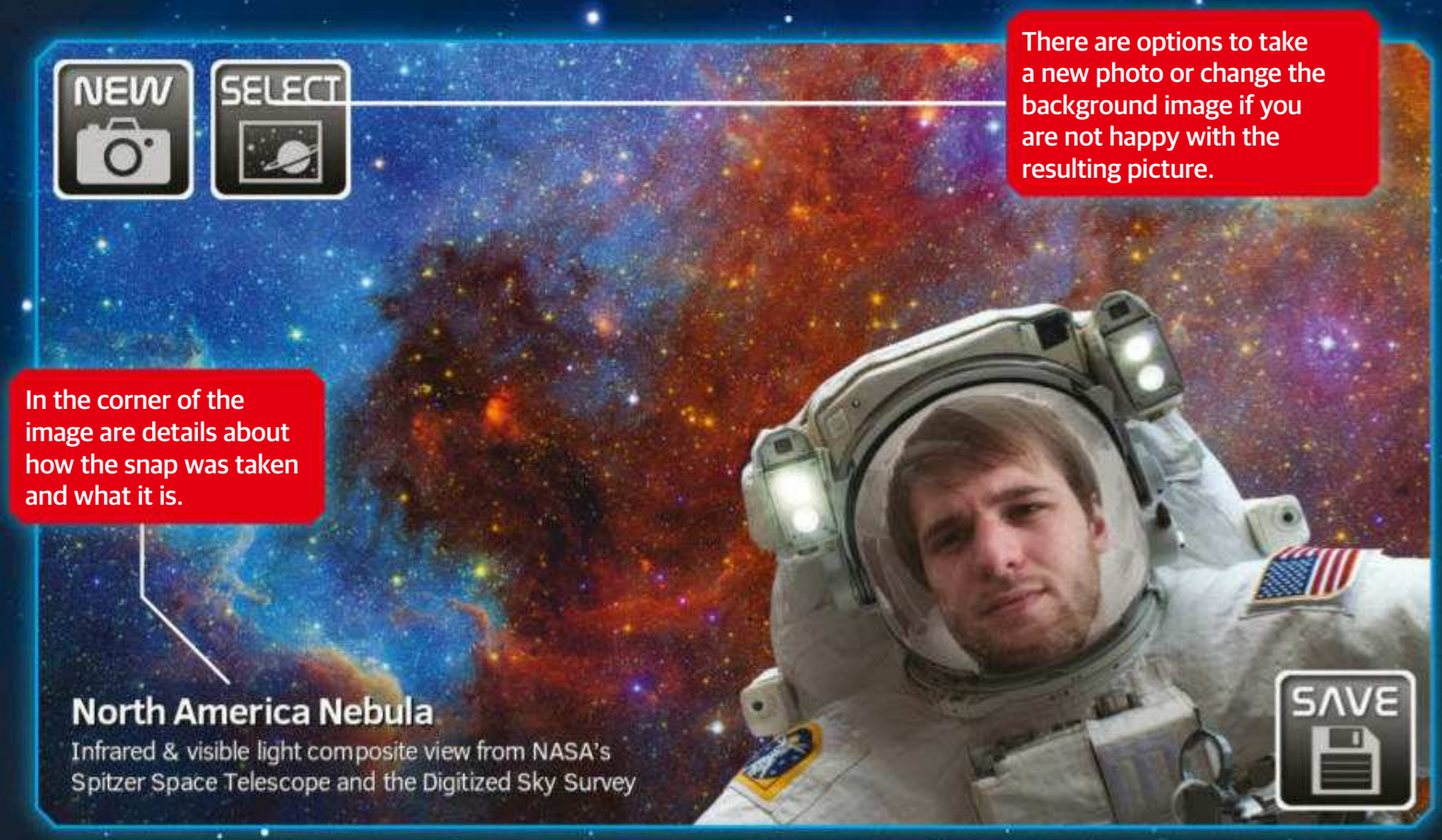
NASA is not renowned for its digital applications on smartphones and virtual-reality devices, but now it has spread its wings with the launch of two new apps that offer a new experience of space.

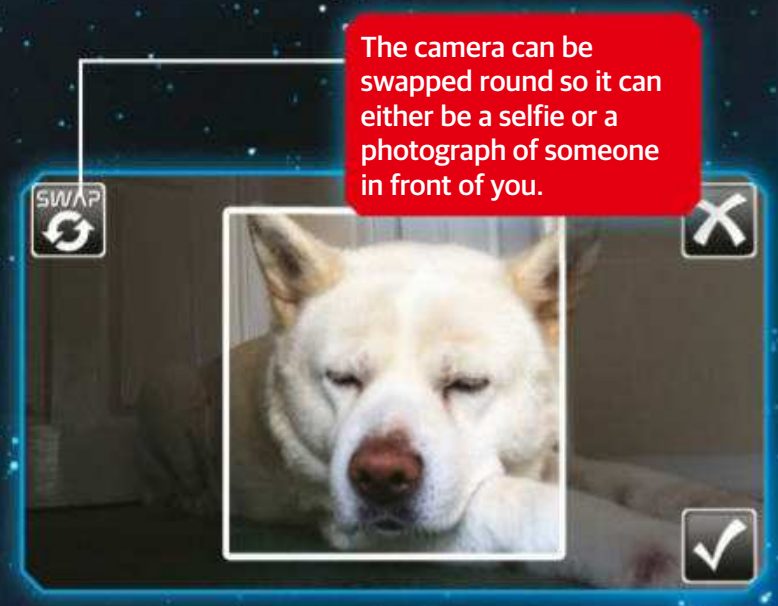
One app is available for iOS and Android devices and gives you a taste of the celestial artwork that NASA has in its gallery, and the other is a virtual reality (VR) tour around the TRAPPIST-1 system.

These apps were created to celebrate the 15th anniversary of the launch of NASA's Spitzer Space Telescope. The infrared eye in the sky has produced countless images invisible to the human eye, and its observations of exoplanets have been key for the field. Spitzer's infrared vision was able to uncover vital characteristics about the TRAPPIST-1 system that have made it the incredibly exciting prospect everyone knows it as today.

The 'NASA Selfies' app takes the user – or whoever the user decides to image – and turns them into an astronaut. By changing the background the astronaut can find themselves in a plethora of different cosmic scenarios. From the Andromeda Galaxy to the star Zeta Ophiuchi, there is a whole host of Spitzer images to choose from.

As for the 'NASA Exoplanet Excursion' virtual reality app, this is a detailed tour through the TRAPPIST-1 system, the seven Earth-sized worlds just 40 light years away. The information collected on the system by Spitzer is narrated and explained throughout the interstellar presentation.





NASA Selfies

Avaliable for: iOS & Android

This gallery flaunts some of the most majestic sights that the universe can offer. The NASA Selfies app takes advantage of all the amazing images that Spitzer has produced over the years, viewing celestial objects in new light and offering a broad variety of contrast colours. With over 30 images to choose from, ranging from stars to galaxies, you can become an astronaut travelling past some breathtaking celestial sights.

This app was created by the Jet Propulsion Laboratory in California, United States, and they have created it with the option to share the resulting masterpiece on different social media platforms, including Facebook, Twitter and Instagram, as well as sending it to your friends.

"There's a plethora of different cosmic scenarios"

QUICK TIPS AND TRICKS



1 When selecting a background image there is an option to pick the image randomly. This will let Lady Luck decide, meaning you could either end up in front of a cloud of gas illuminated by newly formed stars, or a side-on view of a galaxy.



2 Make sure that the face that will be placed in the astronaut helmet is within the white box. There is also the option to switch from the front camera to the back camera, a feature that is available on virtually all modern smartphones.



3 When you have taken the picture, you then have the option to share the image. This will give you the option to message it, email it or post it on whatever social media platform takes your fancy.



4 Once the image is prepared there is a pop-up information section that will appear once the title of the image is pressed in the bottom-left corner of the image. This will provide a more comprehensive description of the image you have chosen.

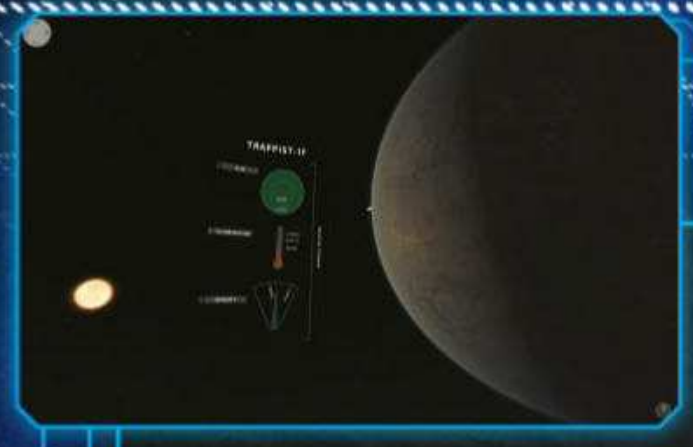
NASA EXOPLANET EXCURSION VR

Avaliable for: YouTube 360-degree, HTC Vive, Oculus Rift



Another strong contribution the Spitzer Space Telescope made was the analysis of the unique TRAPPIST-1 planetary system, which had its news spread further than just the scientific community and even caught the public's attention. Spitzer was able to reveal some important details about the individual planets, and now NASA has created this virtual reality (VR) app in commemoration of its achievements.

The full interactive experience is available for those with a HTC Vive or Oculus Rift VR headset, but for the less fortunate the experience is also available as a 360-degree YouTube video - all that needs to be searched for is the title of the app. The video takes you on a tour of the seven Earth-sized planets located just 40 light years away from Earth. A comparison to Earth for each world emphasises their close resemblance to our home planet, and shows what potential the TRAPPIST-1 system has.



TRAPPIST-1 is a red dwarf star; it is far less powerful than our Sun.



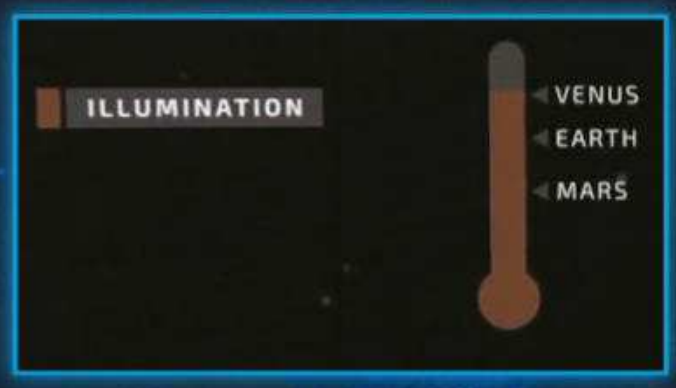
The HTC Vive costs in the region of £499 (or $499)



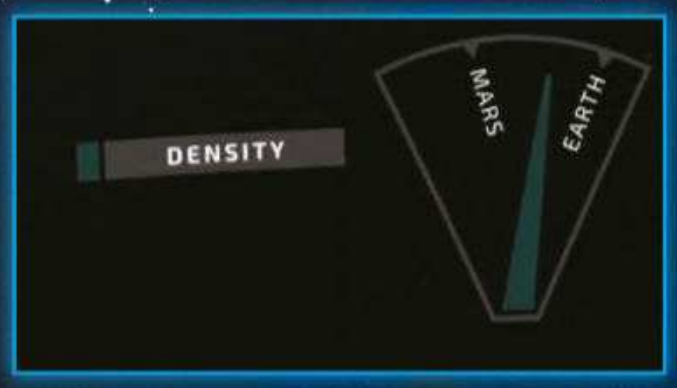
COMPARING CHARACTERISTICS



1 The top of the list of comparative characteristics is the size of the planet, with the coloured region representing the diameter of the world, and the inner circles comparing their size to Earth and Mars. This gives a good sense of scale and also reveals how these planets aren't so far off the size of Earth.



2 The creators of this app have used the term 'illumination', however, I believe the more appropriate term would be 'temperature', as the narration speaks more about whether the planet is hotter or colder in relation to its relative illumination indication.



3 The density of a planet is a strong indication of whether astronomers are looking at rocky planets or a gas planet. Rocky planets have a much higher density measurement, and all the TRAPPIST-1 planets have densities close to Mars and Earth, inferring they are most likely terrestrial.

Each planet was discovered by measuring dips in the star's brightness, also known as 'transits'.



This experience includes many fun facts about each of the seven planets.

Astronomers believe the TRAPPIST-1 system could be twice as old as our Solar System.

The Oculus Rift costs roughly the same at £499 (or $399)



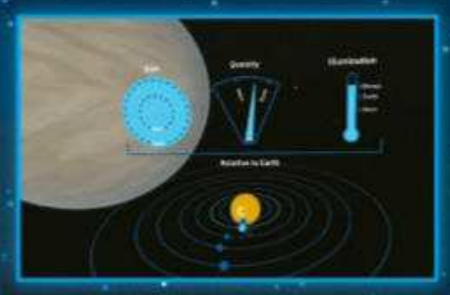
BONUS FEATURES



1 When the blue rings start appearing on the screen, this is the app's way of guiding you on to the next planet. The rings show you the direction in which you need to turn your attention to next.



2 The images of the planets shown in this app are not real images. They are artistic impressions based on the observations made by Spitzer and other ground- and space-based telescopes.



3 A feature only available on the VR-headset version is the 'map' of the TRAPPIST-1 system, indicating which planet you are currently looking at. This appears underneath the comparable characteristics.



4 The journey ends on the planet TRAPPIST-1e, which is the planet most like Earth. Its size, illumination and density are the closest matches to our home planet. This could be the most likely place to harbour any sort of life as we know it.

© NASA/JPL-Caltech

JUPI

DOES IT HAVE A GRO

Astrophysicists think they know why the gas giant's evolution was delayed for two million years

Reported by David Crookes

TER

OWTH DISORDER?

© NASA/JPL-Caltech

What do we know about Jupiter? Rather a lot, as it happens. We know that it's a giant ball made up of mostly hydrogen and helium, that it is the fifth planet from the Sun, that it's over 11-times the diameter of Earth and that if you could mash all of the other seven planets into a big splodge Jupiter would still be 2.5-times more massive.

After the Sun it's the largest body in the Solar System, and it is also very old. But just how old has been the subject of a lot of research over the years, and only recently has the answer emerged. An international group of scientists say Jupiter is roughly as old as the Solar System itself, with the planet's solid core forming about a million years after the Solar System came into being. And yet there is also much evidence, thanks to a fascinating new study, that it suffered some growing pains along the way.

Lead author of the study, Dr Thomas Kruijer, now of the Lawrence Livermore National Laboratory in California, United States, dated Jupiter at some 4.5 billion years old in 2017. Formerly of the University of Münster, Germany, Kruijer sought to study meteorites in close detail. The team looked at tungsten and molybdenum isotopes on iron meteorites found on Earth, knowing that these dense metals would have been in great abundance within the core of bodies many hundreds of kilometres in size at around the time the giant planets formed.

In doing so, they discovered something rather startling. By using molybdenum and tungsten isotope measurements the scientists were able to determine a meteorite's birthplace and age. But they also found that meteorites, which are mostly derived from the collision of asteroids and date back to the early Solar System, could be separated into two genetically distinct groups. These, they discovered, coexisted in different nebular reservoirs between a million and ~3-4 million years after the Solar System formed – and it led to the theory that the formation of Jupiter was the reason why they were kept apart for so long.

"The idea is that the early Solar System contained two types of solid material: one located closer to the Sun than Jupiter's orbit and one further away," explains astrophysicist John Chambers, from the Carnegie Institution for Science. "A leading theory for how Jupiter formed is that it started small and grew larger over time, beginning as a solid planet like Earth, eventually becoming massive enough for its gravity to pull in gas from the solar nebula that surrounded the young Sun. As Jupiter grew it became massive enough that its gravity prevented small [millimetre-to-metre sized] solid particles called 'pebbles' in the solar nebula from crossing Jupiter's orbit. This gave rise to the two separate populations of particle seen in meteorites."

For Jupiter to have produced this effective barrier, Dr Kruijer said the planet's core had to be close to 20 Earth masses within a million years. It then reached 50 Earth masses until at least ~3-4 million years, and eventually grew to 317.8-times the mass of the Earth as it continued to accrete gas around its core. Therein, however, lay another puzzle.

"Dr Krujier et al showed a chronology for Jupiter's growth based on the meteoritic record, but no explanation was given on how it could have taken two million years for Jupiter to pass from ~10 Earth masses to ~50 Earth masses," Julia Venturini tells us. With that in mind, the astrophysicist at the University of Zürich began to delve deeper with

> "A leading theory for how Jupiter formed is that it started small and grew larger over time, beginning solid like Earth" **John Chambers**

How Jupiter was made

Its strange growth pattern was affected by 'baby planets' and pebbles

Jupiter reaches its pebble isolation mass
Jupiter becomes sufficiently large to push away incoming pebbles, thanks to a pressure bump in the surrounding gas. This is known as the pebble isolation mass.

Planetesimals begin to heat
Planetesimals, larger, kilometre-sized rocks become excited by Jupiter's growth – that is, they gain extra energy.

< 1 Myr

1 to 3 Myr

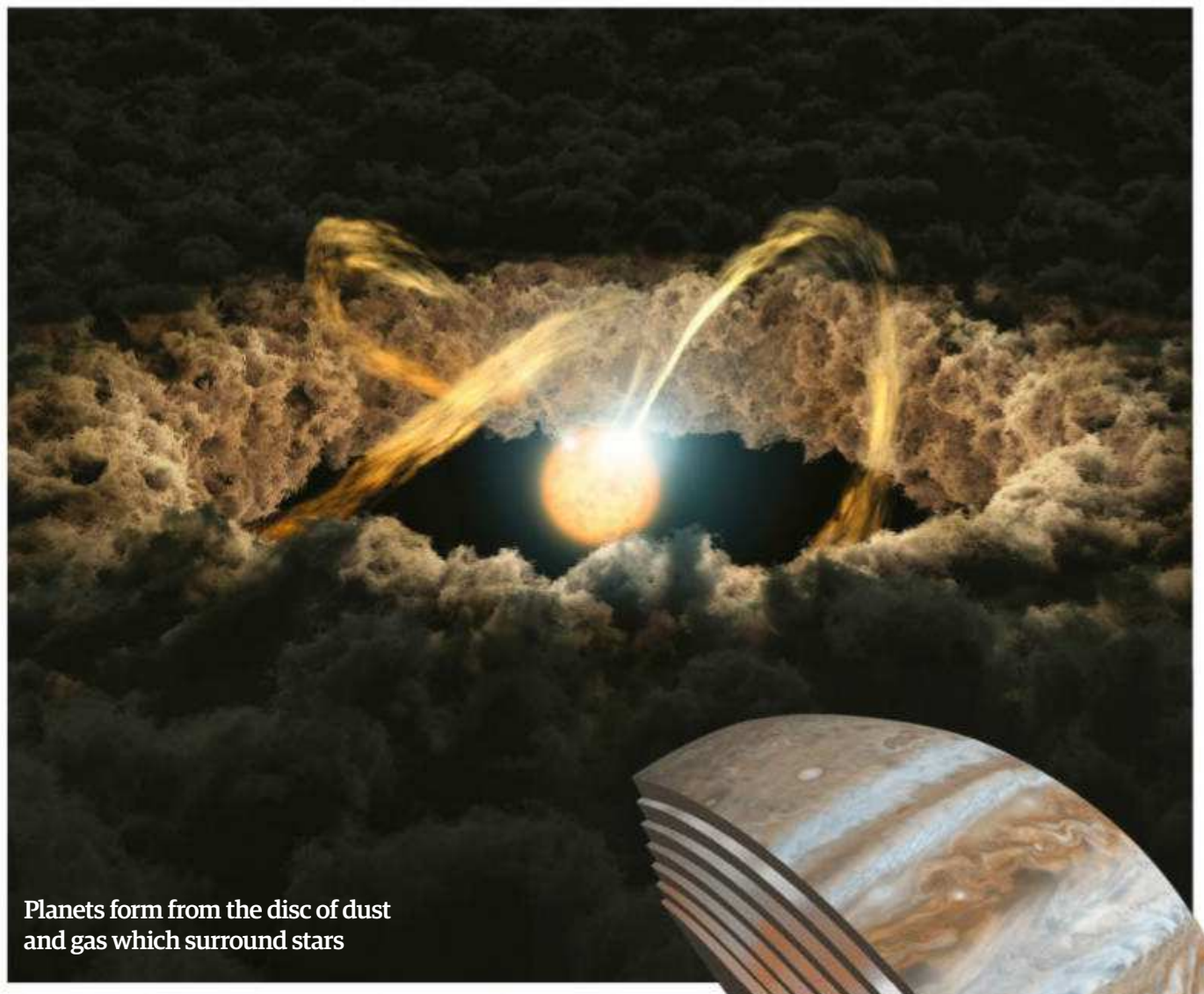
Jupiter gathers pebbles
Tiny, centimetre-sized pieces of rocky material – otherwise known as pebbles – are attracted to Jupiter's core under the influence of gravity, enabling it to grow in mass.

The planetesimals collide
Primordial planetesimals suffer high velocity collisions, leading to destructive collisions. This forms smaller, so-called 'second-generation', planetesimals.

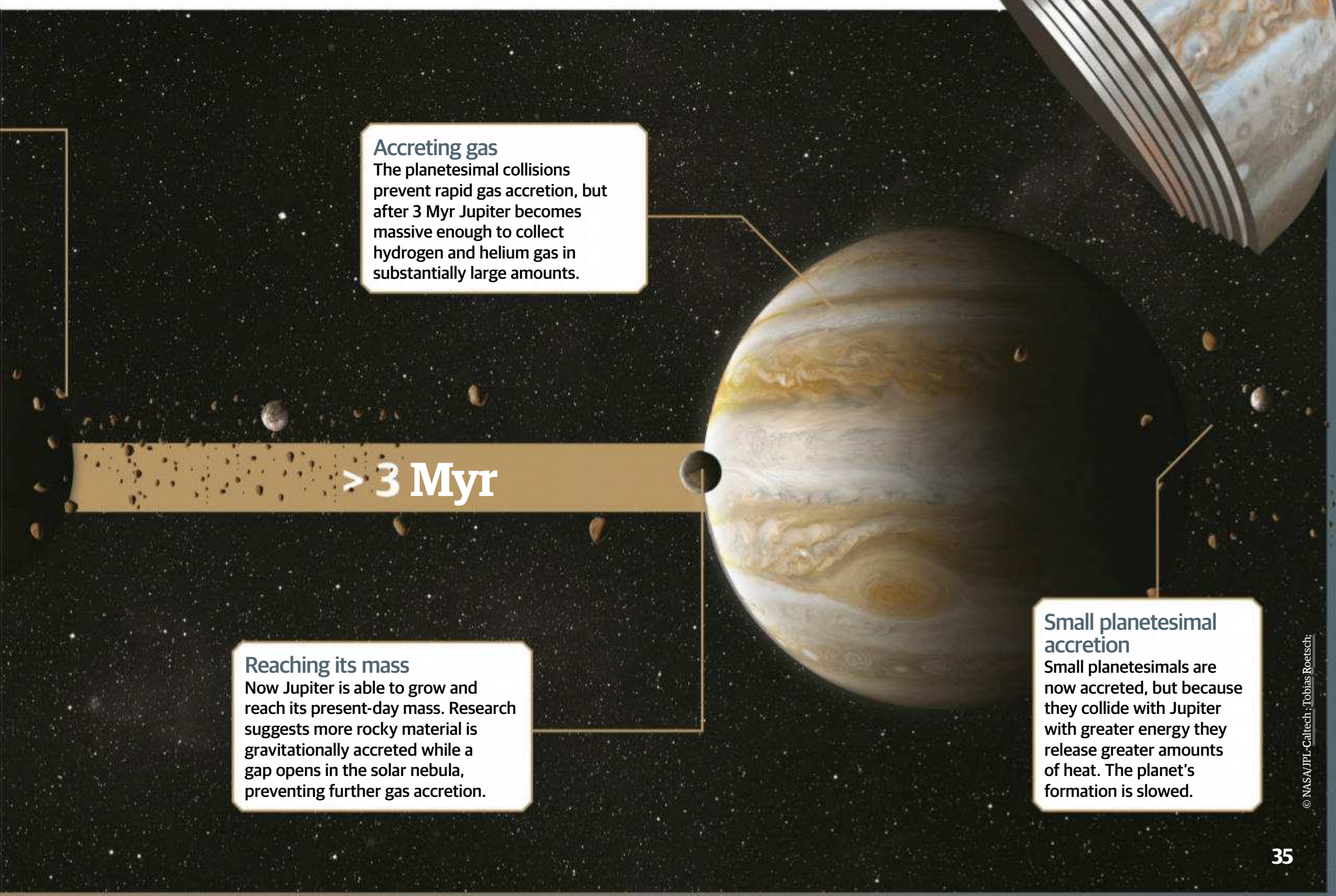
Yann Alibert, science officer of PlanetS. "Kruijer et al demonstrated the time sequence, but did not explore the implication in terms of the formation process. This is what we did," Alibert affirms.

Three models tend to explain how planets form. The most accepted, the core accretion theory, states that planets grow a small rock-ice core and then gravitationally acquire additional mass. They do so by gathering material left over from the creation of the Sun, with the solar wind causing hydrogen and helium to form gas giants and rocky material producing terrestrial planets. But there is an issue with giant planets needing to form fast, since the gas disc around the Sun only lasted for around three to four million years.

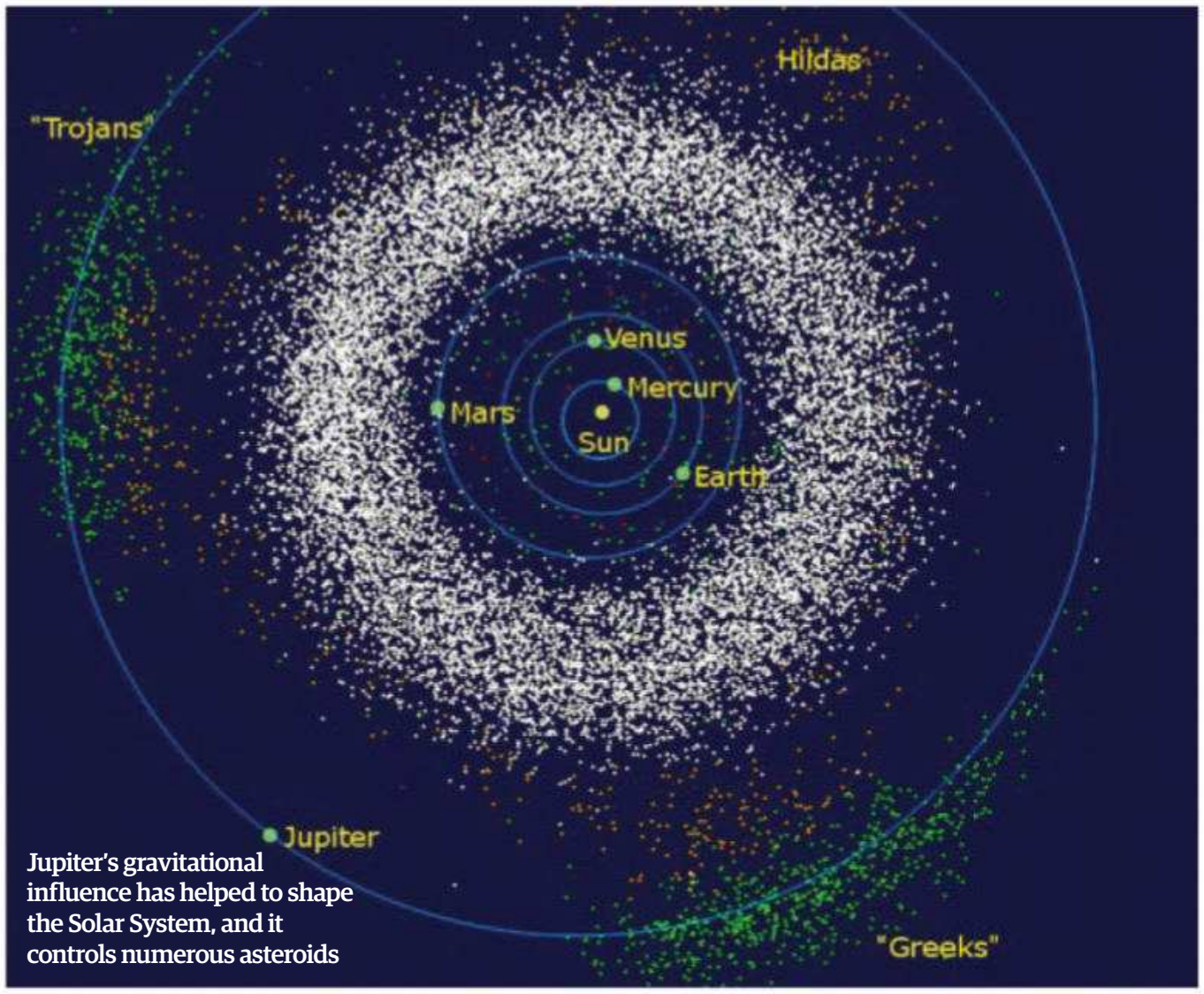
This latter issue has led to the disc instability model which posits that dust and gas clump together early on, then compact quickly to form the giant planets. But there is also the pebble accretion model, which shows that tiny rocks combine quickly to form the large-scale planets. In 2015 it was suggested that the gas-giant planets accreted pebble-sized rocky material formed from dust grains and that this allowed them to build rapidly. Indeed, Dr Harold Levison, an astronomer at the Southwest Research Institute in Colorado, said it was possible for objects such as Jupiter and Saturn to form within a 10-million-year time frame if they gradually accumulated planetary pebbles.



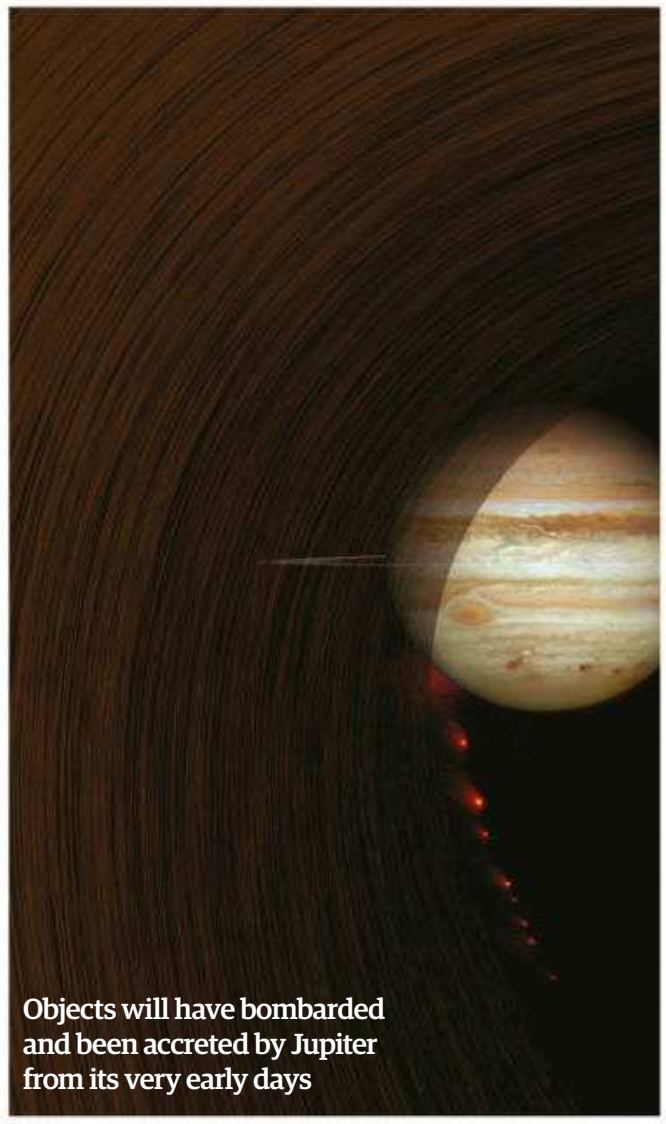
Planets form from the disc of dust and gas which surround stars



© NASA/JPL-Caltech ; Tobias Roetsch;



Jupiter's gravitational influence has helped to shape the Solar System, and it controls numerous asteroids


Objects will have bombarded and been accreted by Jupiter from its very early days

"If the pebbles form too quickly, pebble accretion would lead to the formation of hundreds of icy Earths," said Dr Katherine Kretke, also of SwRI, who co-authored a paper with Levison and Dr Martin Duncan. "The growing cores need some time to fling their competitors away from the pebbles, effectively starving them. This is why only a couple of gas giants formed."

But just why did it take Jupiter so long to grow from ~10 to ~50 Earth masses only to then rapidly spurt to ~317.8? With no other explanation of the meteoric records, Alibert, Venturini and their colleagues got to work on a computer simulation, drawing upon experts in the fields of astrophysics, cosmochemistry and hydrodynamics. Before long, they found that Jupiter had grown over three stages.

First of all, the planetary embryo accreted tiny pebbles that were little more than a centimetre in size. "The protoplanetary discs are full of these pebbles in the first million years" explains Venturini. "They are slowed down by gas drag and they spiral towards the star. When they do so, a planet growing in the disc can intercept the pebbles very efficiently. Indeed, pebble accretion is the fastest way to grow the core of giant planets, so in only one million years a core can grow up to 10 to 20 Earth masses at the position of Jupiter."

Once that mass is reached, she continues, the protoplanet is massive enough to perturb the disc. "As a consequence, the pebbles that normally drift from the outside of the disc to the inside stop drifting and are stuck outside the planet's orbit and cannot be accreted anymore," Alibert explains. "This is what is called the 'pebble isolation mass'."

It is at this point that things become even more intriguing. For at least the next two million years, the theory says Jupiter began to accrete large rocks of around a kilometre in size called planetesimals. Like the pebbles they added mass, but only in small measures. Since a lot of heat was released, they also generated high energy. As a result, very little gas was accreted.

"Planetesimals are harder to accrete than pebbles, especially in the first million years of the disc's lifetime, since planetesimals are still forming and their accretion rate is expected to be low," Venturini tells us. "However, after pebble accretion stops, planetesimals are the only solids that can be accreted. The accretion of solids releases energy because they bombard the protoplanet, transforming their initial gravitational potential energy into kinetic energy that heats the gas of the protoplanet's atmosphere."

This is crucial in explaining why Jupiter's growth slowed down in its early life. Under normal circumstances a forming planet would accrete gas from the disc in which it is embedded due to its gravity, but the ability to do this also depends on how much the atmosphere is able to cool and contract. "Cooling and contraction allows for more gas to enter in the gravitational influence of the planet, and thus allows for more gas to be accumulated in the form of an atmosphere," says Venturini. "If the atmosphere is heated, then cooling will take much longer, and that is exactly the mechanism we are proposing to explain the delayed accretion of gas on to Jupiter."

Only when Jupiter became big enough after three million years of being bombarded by planetesimals was the planet able to accrete large amounts of gas and grow quickly again. That's because, at this stage, the gaseous atmosphere could cool and contract. The findings fit perfectly with the timescale given by the meteorite data. "Now we will extend our new mechanism to check if it also matches the formation of Uranus and Neptune," Alibert says. "If we can explain the formation of these planets with our new scenario it will be a strong support to the hybrid accretion mode."

The academics are certainly thrilled about the results, given the ramifications involved in explaining the formation of Jupiter – the most important event in the formation of the Solar System. "The presence of Jupiter has strong consequences on the way the Earth is today," explains Alibert. "For example, some studies have shown that, without Jupiter, the Earth may have been much bigger, and not habitable [perhaps like Neptune]. Also, some studies have shown that the amount of water on Earth could have been much higher without Jupiter. In this case the Earth could have been an ocean planet, and probably not habitable. Understanding how many habitable planets there are in the universe requires

"Some studies have shown that, without Jupiter, the Earth may have been much bigger, and not habitable" **Yann Alibert**

© NASA; Tobias Roetsch; M. Showalter; H. Raab; Getty/Antonio M. Rosario;

Jupiter's ingredients

There are several layers beneath the storm bands of the surface

Jupiter's core
According to most theories, Jupiter has a solid core made up of rocks, metals and ices. Collectively, these are referred to as heavy elements.

Metallic hydrogen layer
The new model of formation concentrates on the first few million years. The planet then evolved for thousands of millions of years. A layer of metallic hydrogen formed due to high pressure on accreted molecular hydrogen.

A solid mass
The new model assumes the core to be rocky, or rocky and icy, with enough mass to eventually capture gasses from the early solar nebula. It likely accreted pebbles and planetesimals.

Hydrogen and helium layer
Molecular hydrogen and helium form most of the outer layer of Jupiter – a swirl of gas and liquid. This will have been accreted over many millions of years after the planet became massive enough in the third stage.

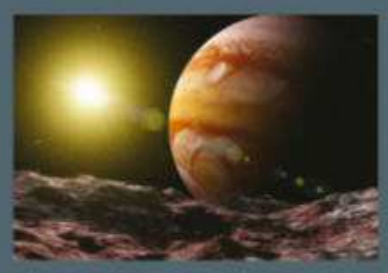
Great Red Spot
There remains no definitive theory to explain how the Great Red Spot of Jupiter formed or even gained its colour, but we know that it's a gigantic storm with winds of up to 680 kilometres (423 miles) per hour.

Atmospheric layers
Jupiter has four atmospheric layers: the troposphere, the stratosphere, the thermosphere and exosphere. Its make-up is similar to that of the Sun in that is it mostly helium and hydrogen – the effect is a blurring between the surface and the atmosphere.

What the meteorites reveal



Jupiter's age
Isotopes in meteorites suggest Jupiter's core was born within a million years.



Jupiter's power
Jupiter once kept two types of iron meteorites apart – they're now mixed together.



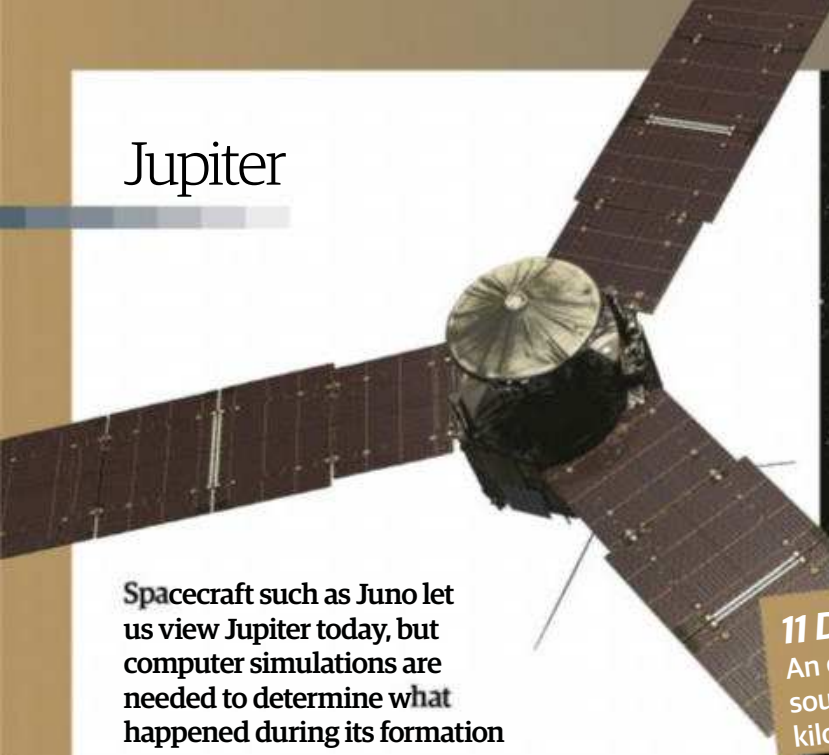
Jupiter's growth
To keep the iron meteorites apart, Jupiter must have been 5 to 16 Earth masses.



Jupiter's disruption
Since the regions of meteorites didn't mix, Jupiter was a disruption.



Jupiter's impact
Jupiter's early birth could explain why our inner Solar System lacks super-Earths.



Spacecraft such as Juno let us view Jupiter today, but computer simulations are needed to determine what happened during its formation

understanding how planetary systems form and evolve, and therefore how giant planets, which dominate the dynamics of planetary systems, form and evolve."

The hypothesis will, of course, be tested. "Philosopher Karl Popper used to say that a scientific hypothesis is impossible to confirm," says Venturini. "The only thing we can do as scientists is try to find evidence to 'falsify' the hypothesis, meaning that we can only discard an hypothesis when we prove it wrong."

One way to prove the scenario wrong could be to find that the meteorite measurements taken by Kruijer were incorrect. Chambers also tells us that core accretion models involve a number of substantial uncertainties. "Predictions from these models have changed several times since core accretion was first suggested about 40 years ago," he says. "It is also possible that the reason for the two distinct meteorite populations has nothing to do with Jupiter, in which case the details of how Jupiter formed are not relevant. For example, Larry Nittler [from the Department of Terrestrial Magnetism at Carnegie] pointed out to me that Jupiter may not have been very effective at separating tiny dust grains into two populations, and yet meteorites also fall into two groups based on the dust grains they contain."

Even so, Venturini believes her theory is on the right track. "It could also be that a different mechanism that is much more likely than the formation of Jupiter may explain the time and space separation of the different types of meteorites," Venturini adds. "But that new scenario should be able to explain how Jupiter's formation played no role in the meteoritic data. As long as our hypothesis explains new evidence our trust in the hypothesis or theory increases, then it stands and, if our hybrid pebble-planetesimal accretion scenario helps to explain the formation of Uranus and Neptune, our scenario will gain more strength."

Certainly, by invoking a hybrid pebble-planetesimal accretion model, the astrophysicists are proposing a shift in the current paradigm of planet formation, putting together different pieces, both observational and theoretical, to build a plausible story for the formation of our planetary system. "We think that this new hybrid scenario is very important as it shows that one must not only look at the mass growth of planets, but also at the energetic aspect," says Alibert. It's a theory we expect will grow in stature.

© NASA/JPL

Top shots of Jupiter

The best views of the gas giant sent back to Earth so far



11 December 2016 - *Juno*
An enhanced-colour view of Jupiter's south pole from an altitude of 52,143 kilometres (32,400 miles)



1 December 2000 - *Cassini*
You can clearly see the Great Red Spot of Jupiter, as well as the innermost Galilean moon, Io



19 May 2017 - *Juno*
Jupiter's bands of light and dark clouds with three white oval storms clearly visible



27 March 2017 - *Juno*
A swirling storm captured during a close fly-by from just 19,956 kilometres (12,400 miles) away



30 June 2016 - *Hubble*
This stunning light show – known as an aurora – was captured using Hubble's ultraviolet capabilities

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SPACE EXPLORATION GETS A BOOST!

NASA has awarded $15 million in support of technological advancements in space missions

NASA has recently financed technology projects that could make spaceflight more sustainable, safer and more cost-efficient. The organisation has handed out a total of $15 million (approximately £12 million) to aid 20 technology and research proposals from 19 small American businesses as part of 'Phase II' of their Small Business Technology Transfer (STTR) program. Each business is collaborating with a research institution from around America to ensure that each proposal is ultimately both feasible and has the potential for commercialisation.

"Our STTR program focuses both entrepreneurs and leading research institutions on NASA's long-term goals, bringing the latest in aerospace research to our programmes," said Jim Reuter, the acting associate administrator for the agency's Space Technology Mission Directorate (STMD) in Washington, United States. "We are excited to see the results of these latest awardees."

Although these technologies are not going to instantly revolutionise the industry, each proposal will boost NASA's space exploration capabilities. There are proposals that intend to model the physics of rocket launches to identify possible improvements, from increasing fuel efficiency to improving the production of food in microgravity, and also harnessing the true potential of CubeSat swarms that can be scattered around the cosmos.

NASA refers to three projects that have been the lucky recipients of a Phase II contract, which lasts for 24 months and has maximum funding of $750,000 (around £570,000), exemplifying the different space exploration divisions that these small businesses hope to improve. The first, led by Continuum Dynamics, Inc and Pennsylvania State University, looks to utilise the capabilities of Distributed Electric Propulsion (DEP) aircraft. This project will research innovative new approaches to build electric, or some form of hybrid, propulsion mechanisms for these aircraft. This project aims to reduce carbon emissions and fuel usage and improve cost efficiency for the United States' military and urban air mobility programs.

Another project has the intention of improving life higher up in the sky, especially space stations such as the collaborative International Space Station (ISS) and the proposed Deep Space Gateway, which is currently going through much planning and discussion. PC Krause and Associates, Inc and Purdue University have come forth with an idea to create a completely new electrical grid for space stations – one that would be able to provide electricity in a highly autonomous and secure manner for space station operations.

Safer start to spaceflight

A lesson of NASA's Space Shuttle missions was that launch is the most dangerous part of an astronaut's adventure into space. Modelling the several aspects of slag accumulation that occur in the firing of the SRMs can make each launch safer for the astronauts, protect the internal instruments and equipment and more fuel efficient so that less fuel is made into a useless by-product.

Improving deep-space capabilities

Space stations such as the ISS and proposed Deep Space Gateway rely on the latest technologies to provide astronauts with a more habitable environment. The development of the Autonomous Power Controller (APC) will provide full control of the most vital form of energy, electricity. This new centralised controller will provide optimal scheduling, failure detection and system restoration while also monitoring the entire system.

The last one mentioned is one that will make the most dangerous part of an astronaut's journey much safer – the launch. Solid Rocket Motors (SRMs) were used in NASA's Space Shuttle program and there are some undeniable concerns about them, one of which is a left-over aluminium oxide material known as slag. This material is a by-product of the combustion process within the rocket, and this can get into the inner workings of a rocket or spacecraft and cause a serious threat. This is why CFD Research Corporation and Mississippi State University are aiming to use highly detailed simulations to learn as much about the slag-accumulation process in spacecraft in order to avoid such scenarios and ultimately make the rockets more fuel efficient.

"STTR focuses both entrepreneurs and leading research institutions on NASA's long-term goals, bringing the latest in aerospace research to our programmes"

More efficient aviation

With the increase in electric cars, aircraft are starting to follow suit. NASA are introducing a line of aircraft that will use electrical hybrid propulsion systems that will make air travel less harmful for the environment with less carbon emission, and will also be more cost efficient. The improvement of DEP aircraft will make the X-57 Maxwell, the first in the resurrected X-plane project, more of a reality since its announcement in 2016.

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KEPLER'S BEST BITS

How this planet-hunting telescope changed our view of the universe

Written by Jonathan O'Callaghan

Before the Kepler space telescope was launched in March 2009, astronomers weren't sure how common planets were in our galaxy. Was our Solar System a rarity, or were there countless other worlds out there awaiting our discovery?

The answer was a resounding 'yes' in favour of the latter with the help of Kepler. The telescope would go on to find more than 2,500 confirmed exoplanets beyond the Solar System, with nearly 3,000 more awaiting confirmation as planets. These have ranged from large uninhabitable gas giants orbiting close to their stars, known as hot Jupiters, to exciting Earth-like worlds orbiting stars both similar and different to our own Sun, some of which could be habitable. Kepler has almost single-handedly spawned a new field of astronomy, and many new telescopes are being designed to either study some of its planets in more detail or continue the hunt for strange new worlds.

The mission has not been without its problems, with the telescope experiencing a major fault in 2013. But it has soldiered on to the point now where it is only limited by the amount of fuel on board. At the time of writing the telescope had very little fuel left, without which it can no longer hunt for planets. By the end of 2018 the mission is expected to end, bringing to a close one of the greatest astronomy missions – let alone exoplanet missions – ever undertaken. Here, we take a look through some of Kepler's biggest moments.

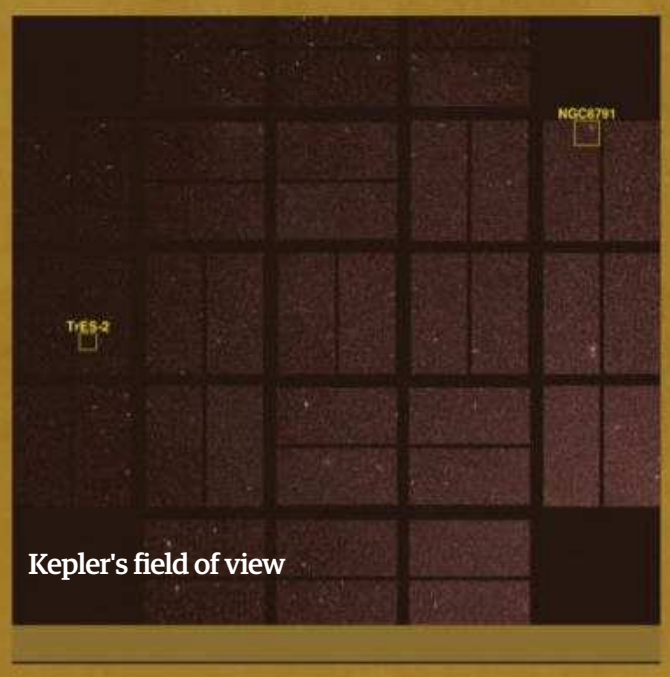
Kepler's first planets

What happened: *Kepler finds its first worlds*
When it happened: *April 2009*

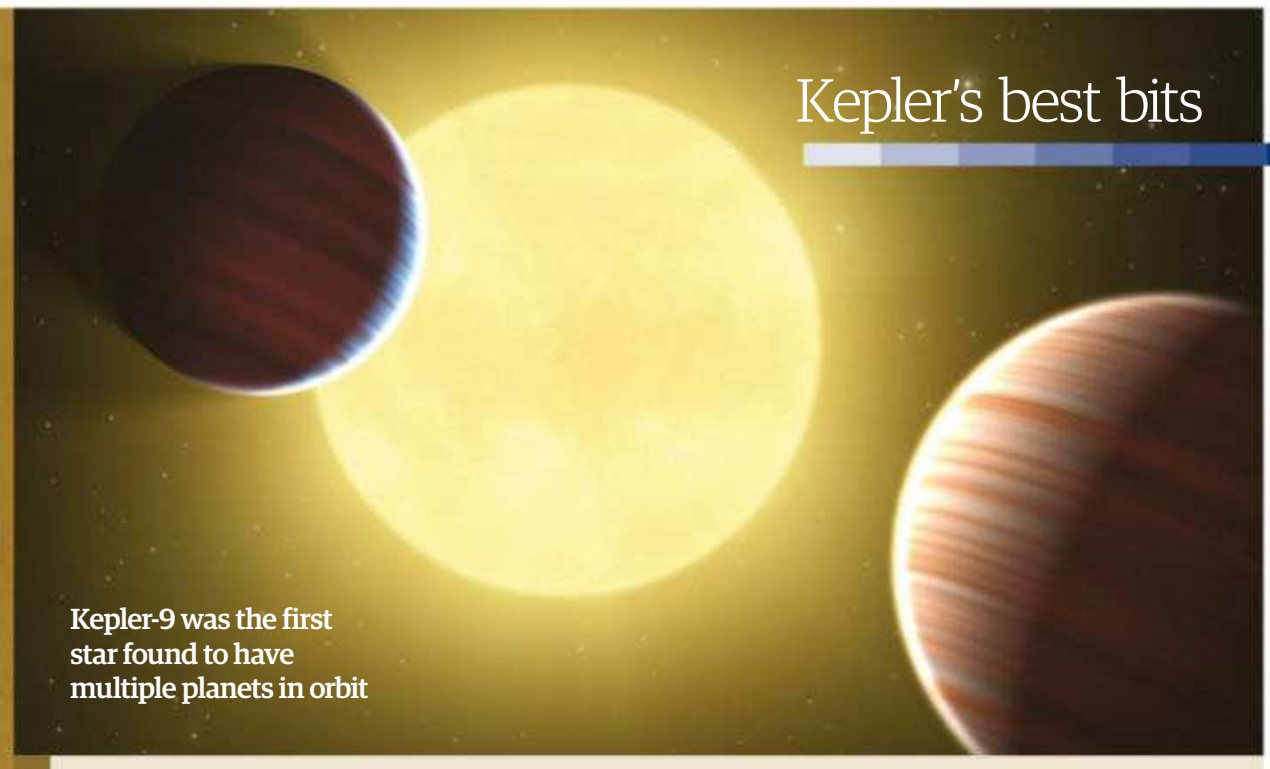
Shortly after launching on 7 March 2009, Kepler spent 67 days in a commissioning phase, checking that its instruments worked to find distant worlds. It would do this by looking for the dip in light of distant stars as planets passed in front, known as the transit method, but scientists weren't sure how successful this method would be.

In April 2009 it detected its first exoplanet, called TrES-2b. The planet, 1.2-times the size of Jupiter and 750 light years away, had been previously discovered, but Kepler's detection of it proved the telescope would be able to find other planets, earning TrES-2b the additional moniker of Kepler-1b.

In August 2009 NASA announced Kepler had confirmed the existence of the known planet, HAT-P-7b, located 1,100 light years from Earth and about 1.5-times the size of Jupiter. Again a redetection, the sensitivity involved in finding this planet proved the telescope would be able find Earth-like worlds beyond the Solar System, if they existed. Following these initial detections Kepler would begin its primary mission in May 2009 lasting three-and-a-half years, which changed the field of exoplanet science forever with the discovery of thousands of worlds, some of which were indeed Earth-like.



Kepler's field of view


Kepler-9 was the first star found to have multiple planets in orbit

The first multi-planet system

What happened: *Kepler finds two planets orbiting the same star*
When it happened: *August 2010*

Today we know of many hundreds of stars that have more than one planet in orbit, and even some systems with as many planets as our own. However, it wasn't until August 2010 that NASA announced Kepler had found its first multi-planet system, two worlds orbiting the star Kepler-9, about 2,000 light years from Earth.

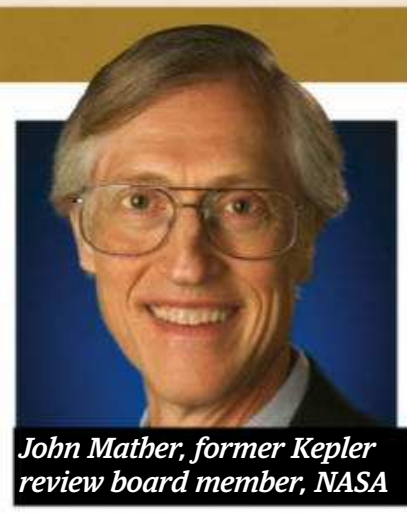
The two worlds were labelled Kepler-9b and Kepler-9c, where the letter denotes the order away from the star, with 'b' being the one orbiting closest to the star. Both were about 0.8-times the size of Jupiter, orbiting their star very closely in a matter of weeks, a class of planet known as hot Jupiters.

The discovery was important as it proved Kepler was capable of finding multi-planet systems, and it also provided astronomers with an opportunity to study the gravitational interaction between two distant planets. This allows the masses of such planets to be measured without the need for follow-up measurements from other telescopes. While this was Kepler's first multi-planet system, the best was still yet to come.

Expert's top moment

"Almost everything has been a surprise"

"The Kepler team changed everything we know about exoplanets. They're everywhere, most are small, and about one quarter of all stars have planets that could be like Earth, maybe alive. Almost everything has been a [tremendous] surprise."


John Mather, former Kepler review board member, NASA

The first rocky planet

What happened: *Kepler finds the first unquestionably rocky planet beyond our Solar System*
When it happened: *January 2011*

Our Solar System plays host to four rocky planets, and many more rocky moons and other bodies. Until Kepler, however, we had yet to find a rocky exoplanet. Larger planets on shorter orbits, like hot Jupiters, were much easier to find as they caused a bigger dip in a star's light and orbited more quickly, so the transits were more noticeable.

In January 2011 that all changed with the announcement of Kepler-10b, the first confirmed rocky exoplanet. About 560 light years from Earth, the planet was nearly four-times the mass of our planet and 1.4-times the size. By confirming the properties of its host star, Kepler-10, scientists were also able to work out the properties of this planet, confirming without doubt that it must be terrestrial. Unfortunately, as the planet orbits its star 20-times closer than Mercury does our Sun, it is almost certain to be a scorching-hot uninhabitable word.



© NASA/JPL-Caltech; Adrian Mann

The first habitable zone planet

What happened: *Kepler finds the first planet where liquid water could exist*
When it happened: *December 2011*

December 2011 was a huge moment in exoplanet science when NASA announced Kepler found the first confirmed planet in the habitable zone of another star. This is the region in which temperatures are not too hot or cold for water to exist, meaning that liquid water could be present on the surface of a planet, and possibly life.

The planet was Kepler-22b, estimated to be about 2.4-times the size of Earth and located about 620 light years from us. It completed an orbit of its star every 289.9 days, with an average temperature expected to be similar to that of Earth.

Initially the discovery caused a huge amount of excitement, with some suggesting it could be an ocean world that contained signs of life. Today the true composition of the planet remains unclear, with some suggesting it could be a gas planet with a rocky core – although the chances of it being a terrestrial world have been ruled out.

Dead in the water

What happened: *Kepler loses its second reaction wheel*
When it happened: *March 2013*

Disaster struck the Kepler mission in May 2013 when the telescope lost its second of four reaction wheels. These wheels are essentially gyroscopes which spin to move the telescope and point it towards distant stars. The telescope needed three of these wheels to work, and after one was lost in July 2012, the worst happened in May 2013 when another failed.

After months of testing, scientists confirmed the telescope would not be able to return to its previous full operation. However, hope was not lost. Scientists came up with an ingenious solution to solve the issue, using the pressure of the Sun's radiation to act as a makeshift third reaction wheel.

Thinking this would only be useful to observe supernovae and other larger phenomena, scientists were surprised in 2014 to find an exoplanet hiding in the latest batch of Kepler data following this repurposing. Two years later a new mission for the telescope had been approved, dubbed K2 or 'second light', and the discovery of exoplanets could continue.



The K2 mission meant Kepler could stay in use

© NASA/JPL-Caltech

"Kepler found the first confirmed planet in the habitable zone of a star"



Kepler-186f bore many similarities to our home planet

A world like our own

What happened: *First discovery of an Earth-sized world in a habitable zone*
When it happened: *April 2014*

Arguably Kepler's most important and publicised discovery came in April 2014 with the announcement of Kepler-186f. This was the first Earth-sized world ever found in the habitable zone of another star, and raised the tantalising prospect that there could be other worlds like ours elsewhere in the galaxy, and possibly even life.

This planet was just 1.2-times the size of Earth, and was at a distance from its star where liquid water could exist. While the mass of the planet located about 500 light years away remained uncertain, best estimates suggested that a planet of this size was likely to be rocky. The only thing preventing this being heralded as a true 'Earth 2.0' was that it orbited a red dwarf star, one that was considerably dimmer than our own Sun.

While these are the most numerous stars in the galaxy they are prone to bursts of radiation, and Kepler-186f's relative proximity to its star (40 per cent that of Earth's orbit) raised questions about its habitability. It remains a key discovery in the history of exoplanet science, though, proving that there were other worlds like ours out there. Now we just had to find one orbiting a star like our Sun – and scientists wouldn't have to wait long...

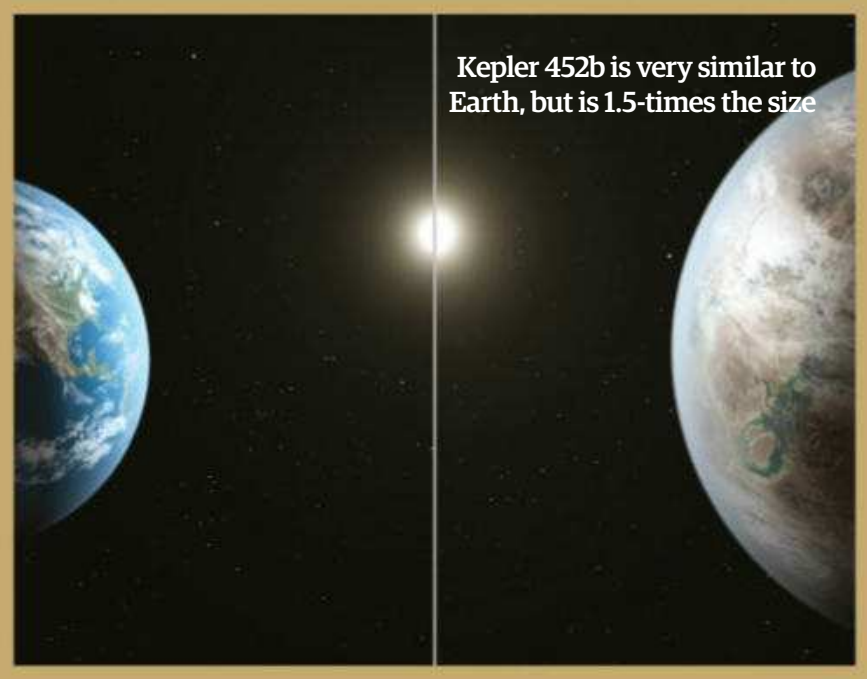
Earth's cousin discovered

What happened: *First Earth-sized planet found orbiting a Sun-like star*
When it happened: *July 2015*

While Kepler-186f's discovery stunned scientists, the announcement of Kepler-452b in July 2015 blew them away. Located about 1,400 light years from Earth, this was the first planet similar in size to our own found to be orbiting a Sun-like star.

The planet itself was estimated to be about 1.5-times the size of ours, orbiting at almost the exact distance Earth does our Sun. Meanwhile its star, Kepler-452, was about 1.1-times the radius of our Sun and a very similar mass. Some heralded this planet as the first true 'Earth 2.0', but others noted it was more likely a cousin of our world.

Its larger size and mass suggested it was probably a 'super-Earth', a rocky planet much larger than our own. Its star was also noted to be about 1.5 billion years older than the Sun, meaning that Kepler-452b was more a glimpse into the future, rather than a glimpse at a similar planet right now. That didn't stop this planet being lauded as one of Kepler's most significant discoveries though.



Kepler 452b is very similar to Earth, but is 1.5-times the size

Expert's top moment

"Observations of Neptune and Triton"

"I had my key Kepler moment watching a time-lapse of the 2014/2015 observations of Neptune and its moon Triton made during the extended Kepler mission (K2). To me, this illustration of an eternal two-body dance in the outskirts of the Solar System is somehow more touching than a stellar light curve."



René Heller, astrophysicist, Max Planck Institute for Solar System Research

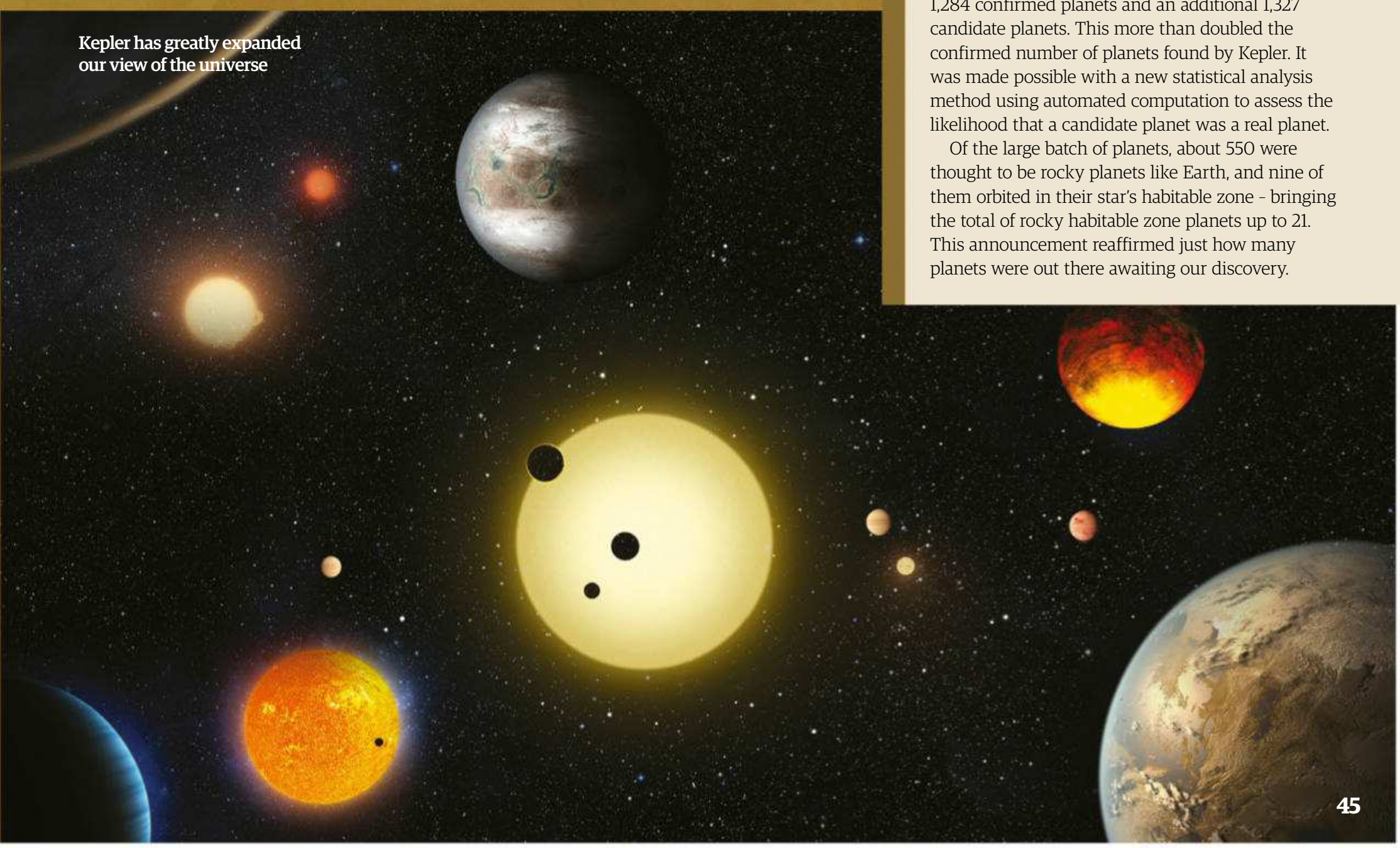
Planet bonanza

What happened: *Kepler's biggest haul of planets ever*
When it happened: *May 2016*

For Kepler to confirm a planet exists, it typically needs to observe three transits of the planet around a star. Any planet with less transits is dubbed a candidate planet, which is why planets in Earth-like orbits are had to find, as three transits can take three years or more.

In May 2016 NASA announced its biggest haul of planets yet from Kepler data – a total of 1,284 confirmed planets and an additional 1,327 candidate planets. This more than doubled the confirmed number of planets found by Kepler. It was made possible with a new statistical analysis method using automated computation to assess the likelihood that a candidate planet was a real planet.

Of the large batch of planets, about 550 were thought to be rocky planets like Earth, and nine of them orbited in their star's habitable zone – bringing the total of rocky habitable zone planets up to 21. This announcement reaffirmed just how many planets were out there awaiting our discovery.



Kepler has greatly expanded our view of the universe



Kepler confirmed there are other stars with their own planetary systems

A mini Solar System

What happened: *First eight-planet exoplanet system discovered*
When it happened: *December 2017*

Kepler had begun its mission finding just single planets in orbit around other stars, so scientists were pleasantly surprised in December 2017 when, after many other multi-planet discoveries, Kepler found the most populated exoplanet system known so far – one with eight planets in it, the same as our own Solar System.

This system orbited the star Kepler-90 about 2,545 light years away, with the eighth planet, Kepler-90i, an extremely hot rocky planet that orbited its star in just 14.4 days. While other planets in this system had been discovered before, clever use of artificial intelligence found this latest one. Machine learning tools were used to 'learn' to identify planets so that by looking through old Kepler data they could confirm planets that had been hiding in it. Aside from being a fascinating multi-planet system, albeit one with little prospect of life owing to how close the planets orbit their star, the discovery suggested this same method could be used to find many more planets in Kepler's data.

Expert's top moment

"Finding there could be more planets than stars"

"Before the Kepler space telescope launched, we did not know whether exoplanets were rare or common in the galaxy. Thanks to Kepler and the research community, we now know there could be more planets than stars."



Paul Hertz, Astrophysics Division director at NASA Headquarters

"Kepler has redefined our knowledge of worlds beyond the Solar System, showing that exoplanets are not only not rare, but plentiful in the galaxy"



The mission nears its end

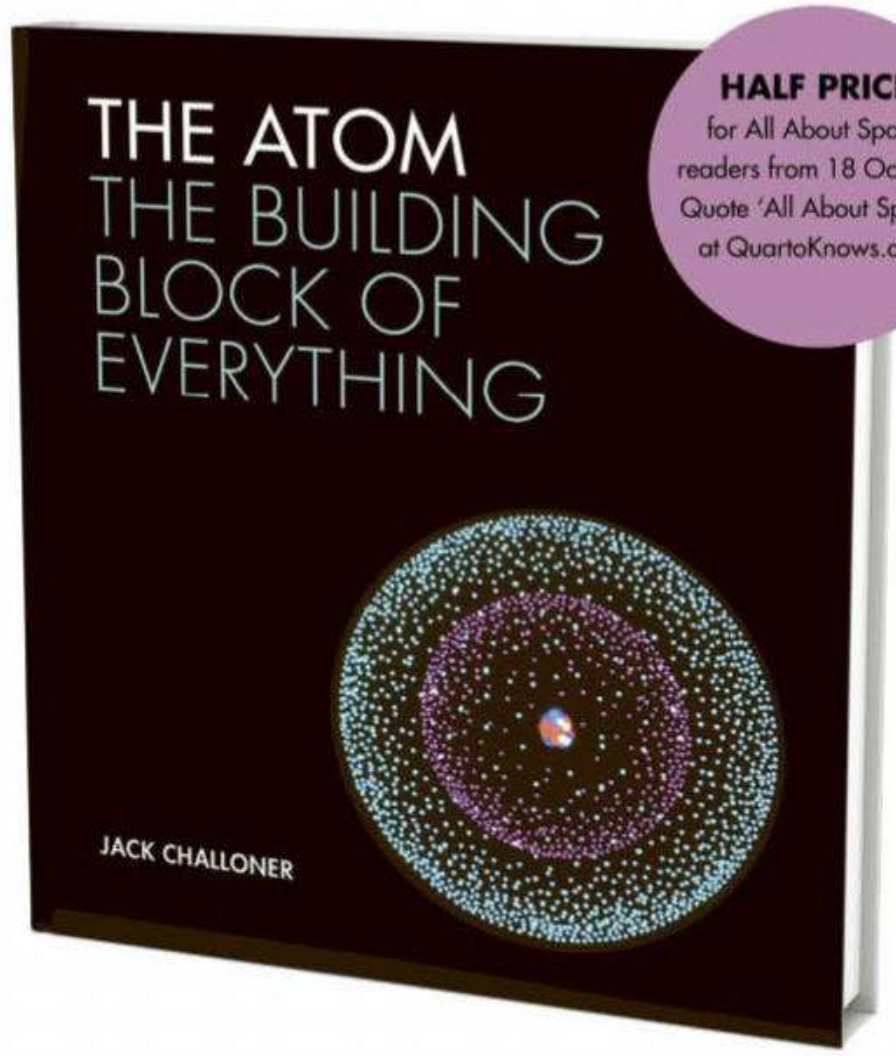
What happened: *Kepler starts running out of fuel*
When it happened: *March 2018*

In March 2018 NASA revealed that Kepler was running out of fuel, meaning the finale of the mission was near. By the end of 2018 they are expecting the telescope to stop working (at the time of writing it is still operational), bringing this decade-long search for exoplanets to an end.

While Kepler doesn't have a fuel meter on board, scientists could monitor how much fuel was available by monitoring the pressure in its tank, and without fuel it could no longer point at stars and send data back to Earth. It was known that the telescope only had enough fuel to likely last until some time in 2018, but the announcement was no less sombre.

Kepler has redefined our knowledge of worlds beyond the Solar System, showing that exoplanets are not only not rare, but plentiful in the galaxy. Other planet-hunting missions have since sprung up to follow on from the findings, such as NASA's recently launched Transiting Exoplanet Survey Satellite (TESS), but none will change our views of our place in the universe quite like Kepler did – at least until we find a true Earth 2.0, one that might really be just like home.

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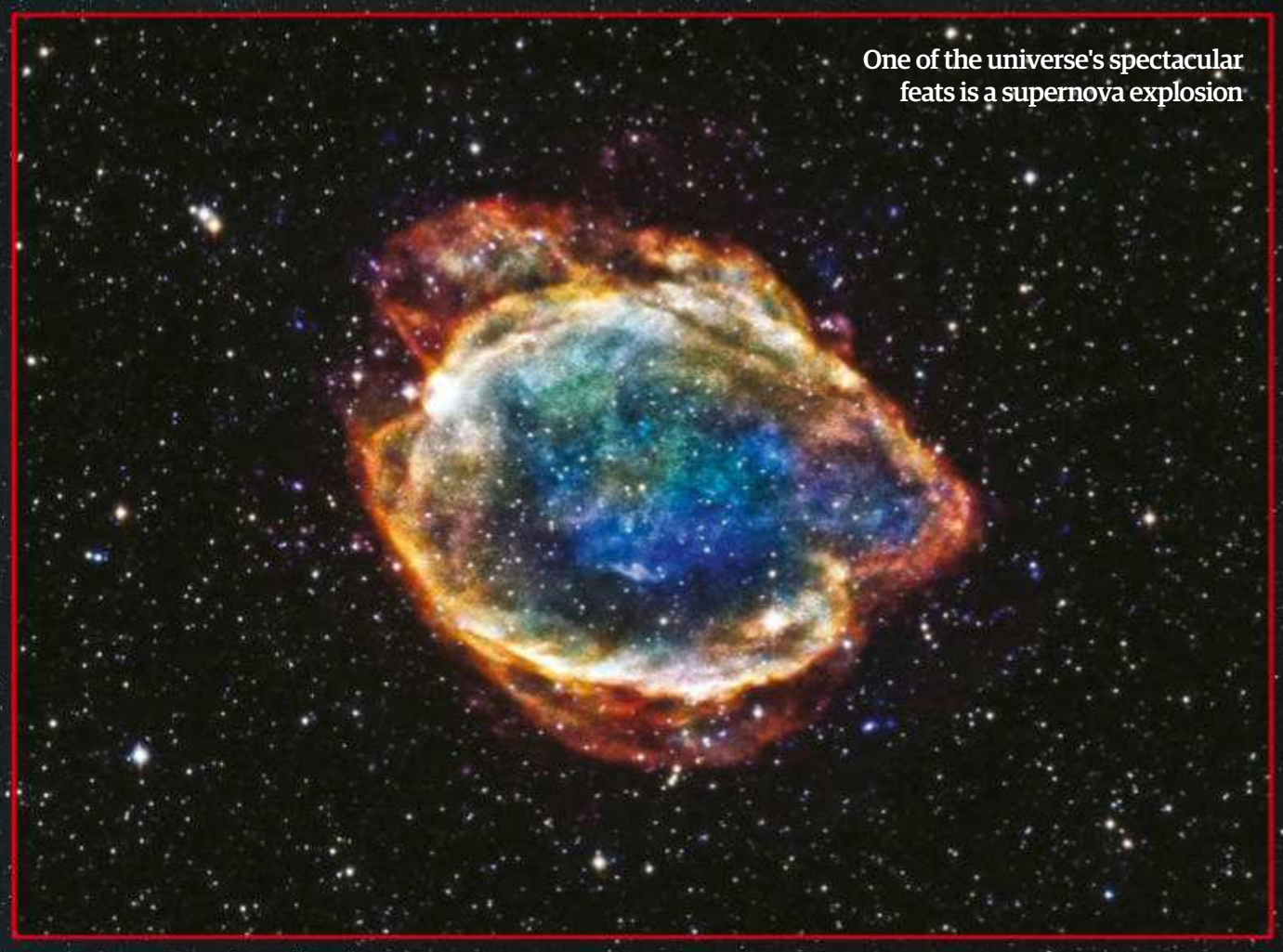
THE IMPOSSIBLE STAR

+10 OTHER SPACE OBJECTS THAT DEFY THE UNIVERSE

— Written by Colin Stuart —

Stars, like people, come in different sizes. Most stars in the universe are smaller than our own Sun – 75 per cent are diminutive, cool red dwarfs. These can be as tiny as a tenth of a solar mass. Move up the spectrum and you start to find beasts tipping the cosmic scales at tens of solar masses, before reaching the monsters weighing in at over 100-times the mass of the Sun. But where is the limit? Until recently astronomers thought the ceiling was approximately 150 solar masses. Any star bigger than this would create so much energy that the outward pressure from all the light particles would rip the star apart.

Imagine the surprise when astronomers found a star known as R136a1 – it has an estimated mass of 315 solar masses, more than double the mass a star is supposed to be able to obtain. The mystery deepened when other massive stars, many heavier than 200 solar masses, were also found lurking in the same part of the space: the Tarantula Nebula. It has forced researchers to return to the drawing board to explain how these stars grew so big.



One of the universe's spectacular feats is a supernova explosion

1 THE CHAMPAGNE SUPERNOVA

One of the universe's most spectacular feats is a supernova explosion – they can often outshine the collective lustre of an entire galaxy.

Supernovae come in different types depending on what causes the initial detonation. A particularly famous breed is the Type Ia supernova. These occur when two stars are orbiting around each other. When one of the pair dies it forms a compact object known as a white dwarf, and its strong gravitational pull starts pulling gas from its neighbour. Over 85 years ago, Indian-American astrophysicist Subrahmanyan Chandrasekhar calculated that there's a maximum mass the white dwarf can reach before it ends its life in a violent explosion – a supernova. This 'Chandrasekhar Limit' is 1.4 solar masses; if a white dwarf has less than this mass, it will remain a white dwarf.

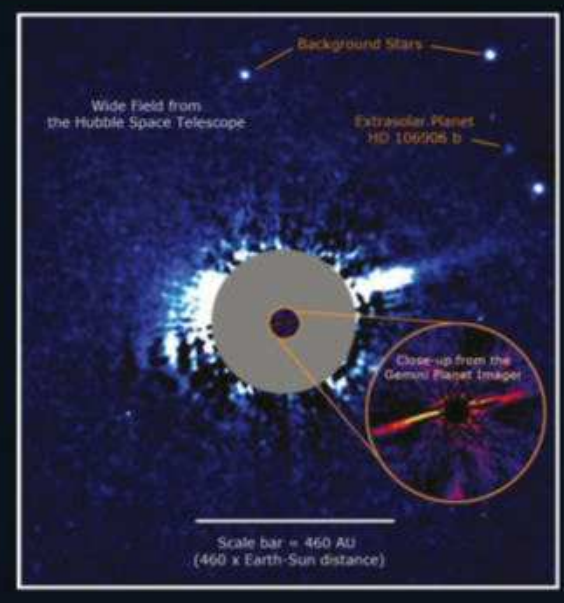
Yet over the last decade astronomers have found 'superluminous supernovae' – explosions that seem to have burned through more mass than the Chandrasekhar Limit allows. The first, SN 2003fg, was dubbed the 'Champagne Supernova'. At present there is no widely accepted explanation for why they seem to defy the laws of physics.

2 A PLANET THAT DOESN'T MAKE SENSE

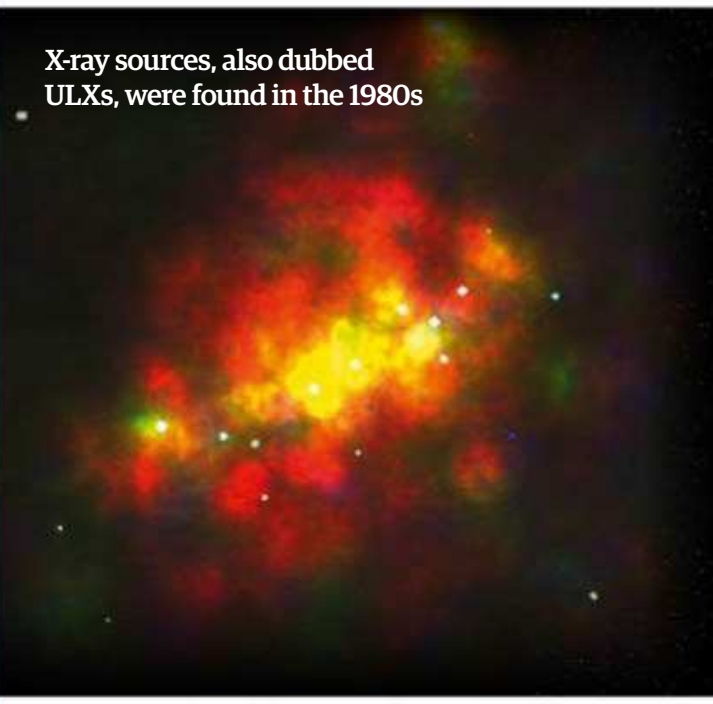
Everything about exoplanet HD 106906 b is unusual. Not only is it super-heavy – 11-times the mass of Jupiter, our Solar System's heaviest planet – it is also marooned in the dark reaches of its stellar neighbourhood. It orbits its star 650-times the distance Earth is from the Sun. Said another way, that's over 16-times the average Sun-Pluto distance!

Our conventional models of planetary formation can't square the presence of such a big planet that far from its host star. Planets are thought to form from a flat disc around a young star. The further out you travel in the disc, the fewer building blocks there are from which to fashion orbiting worlds.

One idea is that it is less of a planet and more of a little brother. Perhaps a tiny star formed at the same time as its bigger sibling. The trouble is that in binary systems the bigger partner is normally no more than ten-times the mass of its companion. In the case of HD 106906 b, the size difference is a factor of one hundred. How it came to be there remains a mystery.



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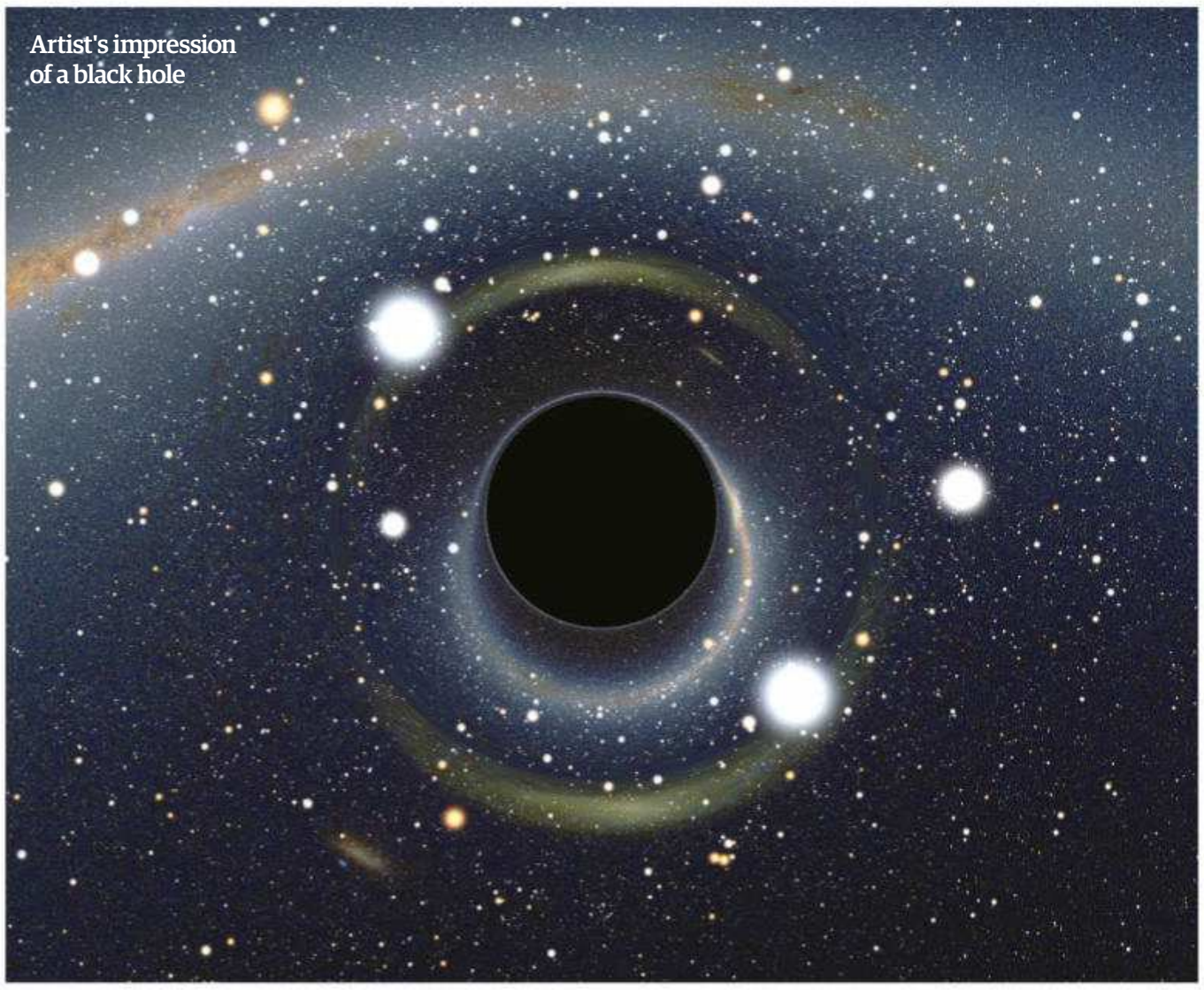
X-ray sources, also dubbed ULXs, were found in the 1980s

3 THE EXTREME X-RAY SOURCES THAT DEFY EDDINGTON

Of all the things currently puzzling astronomers, one of the most troubling and stubborn mysteries surrounds ultra-luminous X-ray sources (ULXs). First discovered in the 1980s, they are, as their name suggests, very bright emitters of X-rays.

At first the finger was pointed at black holes. As material spirals towards the interior of a black hole it becomes super-heated and glows in X-rays. The more massive the black hole, the faster material is pulled in and the more energetic the X-rays. However, ULXs seemed too bright, even for black holes.

Then astronomers found that the light from some ULXs pulsates. That suggested the source might be a rapidly rotating neutron star – or pulsar – instead. But the Eddington limit tells us the maximum brightness a pulsar can have, and these ULXs appear to be 100-times brighter than that. So either these sources defy the laws of physics or there's something else at play. It could be that the X-rays are directed into narrow beams. If that's the case then the Eddington limit isn't exceeded because the source isn't that bright in all directions as we'd assumed.



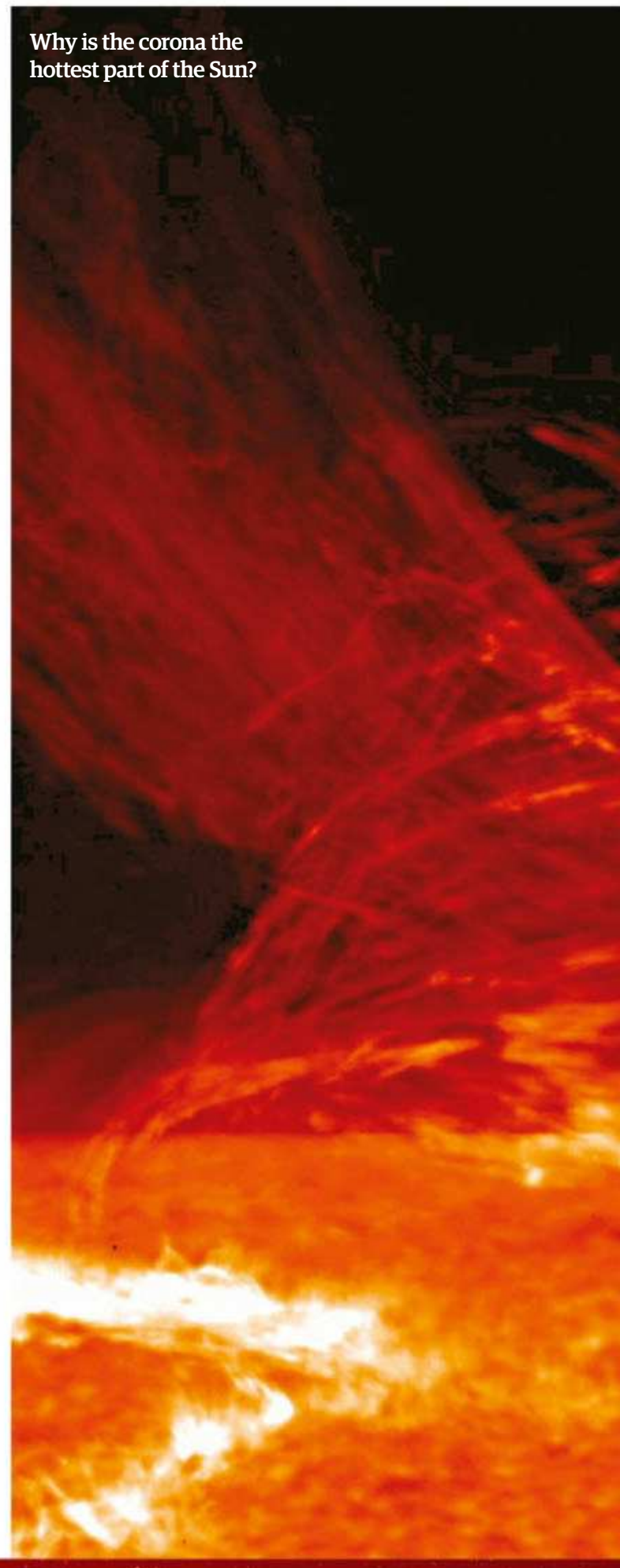
Artist's impression of a black hole

4 THE BLACK HOLE THAT'S JUST TOO BIG

Black holes represent the universe at its most extreme. They are regions of space so warped that anything venturing too close is doomed to oblivion. But without them we probably wouldn't be here either. These gravitational demons are thought to be the seeds around which galaxies like our own Milky Way are formed. At the very heart of our galaxy, and every other, lies a supermassive black hole binding the stars together.

Normally the size of the black hole tallies with the size of the galaxy – the bigger the black hole the bigger the galaxy. As a galaxy grows its black hole feeds and gets bigger, too. But that rule goes out the window with a galaxy known as WISE1029+0501. It has a central black hole far bigger than it should be. That might mean something else has been helping it bulk up – something we haven't considered before.

The mystery deepened in early 2018 when observations with the Atacama Large Millimeter/submillimeter Array (ALMA) showed the outflow of gas from the black hole has less of an effect on the surrounding galactic gas than expected, reinforcing the idea that the two systems aren't in lock-step.



Why is the corona the hottest part of the Sun?

© NASA/JAXA; Alain r; Nature Astronomy (2018);



The weird nebula may reveal the future of our Sun

5 THE INSIDE-OUT NEBULA

Nothing lasts forever. Even our own Sun will die eventually. It will swell into a red giant before puffing its outer layers into space to form a beautiful planetary nebula. Astronomers are confident that this is the fate awaiting our star because they have seen it happen many times before across the universe. Yet one planetary nebula in particular is causing quite a stir – it appears to be inside out.

In 2018 astronomers were studying the planetary nebula known as HuBi 1, which sits around 17,000 light years from Earth. They soon noticed something odd about the way its gas is ionised. Ionisation is the process by which electrons are stripped away from atoms to create charged particles known as 'ions'. Normally the inner regions of a planetary nebula – where it's hotter – are more ionised than the cooler outer shell, yet with HuBi 1 it's the other way around. Before this discovery such a scenario was thought to be impossible.

One potential explanation is that the star briefly came back to life, creating a shockwave that moved out through the surrounding gas. The shockwave was so energetic that it passed straight through the inner gas, only ionising the outer gas.

6 THE CORONAL HEATING PROBLEM

It may be one of the most familiar objects in the sky, but there is a persistent mystery surrounding our Sun: why is its outer layer so hot?

If you start in the core of our star and work outwards through it layers, the temperature continues to drop through the radiative zone and convective zone, out through its visible surface, the photosphere, to the darkness of space. But that's where things get weird. The photosphere has a temperature of around 6,000 degrees Celsius (10,832 degrees Fahrenheit), but by the time you reach the corona – the Sun's tenuous outer layer – it climbs again to several million degrees. This coronal heating problem has stumped astronomers for decades, and they're desperate for answers.

The recently launched Parker Solar Probe could well help, as it will fly closer to the Sun that any mission before it. Living up close and personal with the corona could finally tell us why things don't continue to cool the further you move from the core, the source of the Sun's immense power.

7 THE WHOLE UNIVERSE

The fact our universe has anything left in it is more perplexing than any of those amazing things it contains. Shortly after the Big Bang some of the new cosmos' energy was turned into particles. Crucially, however, this process should have created equal quantities of matter and antimatter – a reflection of ordinary matter with the opposite electric charge. In the billions of years since, the matter and antimatter should have recombined and disappeared back into energy. The universe should be a sea of energy, without islands full of galaxies, stars and planets. That you're even here to read this is testament to the fact that clearly never happened.

It seems our universe has a slight preference for matter over antimatter. For every billion antimatter particles spawned in the cosmos' infancy, a billion and one matter particles appeared. Everything we see in the universe is made from those leftover particles that didn't have an antimatter partner to disappear with. Exactly why this happened is one of the most enduring mysteries in physics, and experiments around the world are desperately seeking an answer. In October 2017, physicists at CERN found that matter and antimatter have identical magnetic properties, ruling that out as the reason for the discrepancy.

The entire universe offers plenty to puzzle astronomers

8 GALAXY WITHOUT DARK MATTER

Astronomers have become confident that most of the matter in the universe is made of a shadowy substance called dark matter. It is the glue that binds galaxies together. Another way to think of it is as the scaffold on which the universe's construction projects are built. So it was shocking to find a galaxy seemingly devoid of it earlier this year. Known as NGC 1052-DF2, its lack of dark matter was discovered using the Dragonfly Telephoto Array in New Mexico.

The team behind the discovery studied ten star clusters orbiting close to the galaxy. They were travelling far slower than expected, suggesting there's scant gravitational pull from local dark matter to accelerate them to high speeds. The job now is to figure out how the 10-billion-year-old galaxy formed without it. Some are calling it the impossible galaxy. It could turn out to be a blow for an alternative theory to dark matter: modified gravity. Advocates for the theory say gravity works differently at different scales. Yet that would affect all galaxies equally. The fact this one is missing dark matter suggests the shadowy substance is really out there, just not here.



Observations of NGC 1052-DF2 show lack of dark matter

© NASA/ESA; ESO; CERN; Adam Block/Mount Lemmon SkyCenter/University of Arizona



The Large Hadron Collider is currently trying to solve cosmic mysteries

9 THE MYSTERIOUS MOON OF NEPTUNE

The outermost planet's largest moon is a real oddball. Triton is the largest irregular satellite in the Solar System. That means it orbits in the opposite direction to the spin of its host planet – clockwise around a planet that twirls anti-clockwise. While fairly common for tiny moons of Jupiter and Saturn, Triton is over ten-times the diameter of those.

Moon-formation models suggest that such a sizeable satellite couldn't have formed in such a backwards orbit. The irregulars are normally captured objects like asteroids or comets drawn in by a planet's gravity, set spinning the other way. Triton's much too big for that: it would likely have crashed headlong into Neptune. So how did it get there? One model suggests it had a partner in crime. If Neptune drew in two objects simultaneously from the nearby Kuiper Belt then the gravity of the sidekick might have slowed Triton sufficiently to be captured about-face. However, that good Samaritan satellite is conveniently no longer about. Where did it go?

It's a puzzle that remains unsolved. Cracking it might provide a vital clue in understanding how our Solar System came to look the way it does today.



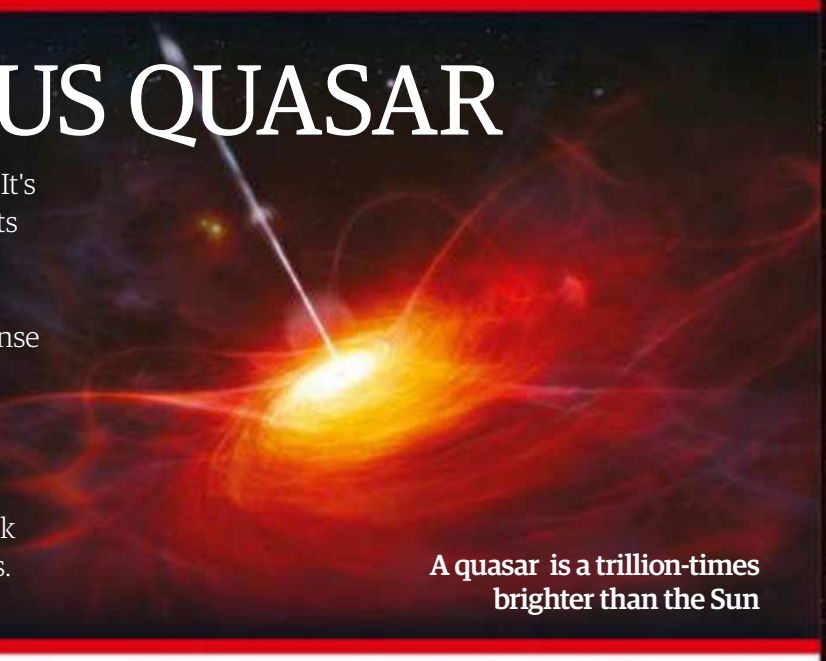
Neptune's Triton is an unusual moon

10 THE CASE OF THE CURIOUS QUASAR

Imagine an object so bright it can be seen almost all the way across the visible universe, despite the fact it's smaller than the Solar System. These amazing objects are known as 'quasars' – a contraction of quasi-stellar object. They look like stars, but they are so far away that any star's light would have long since faded.

Instead they are the glutinous black holes at the centre of the first galaxies, chowing down on stars and gas. But one quasar seemingly flies in the faces of the received wisdom about these enigmatic objects, SDSS J010013.02+280225.8. It's 429 trillion-times brighter than the Sun and sits over 12 billion light years from Earth.

Quasar models suggest it shouldn't be that bright. As the black hole feeds it produces intense radiation that's thought to blow remaining gas away from the centre, limiting the future food supply. There simply shouldn't be enough on the menu to power such a monster. It means astrophysicists are looking again and how black holes consume and shape the heart of galaxies.



A quasar is a trillion-times brighter than the Sun

Instant Expert

Solar cycles

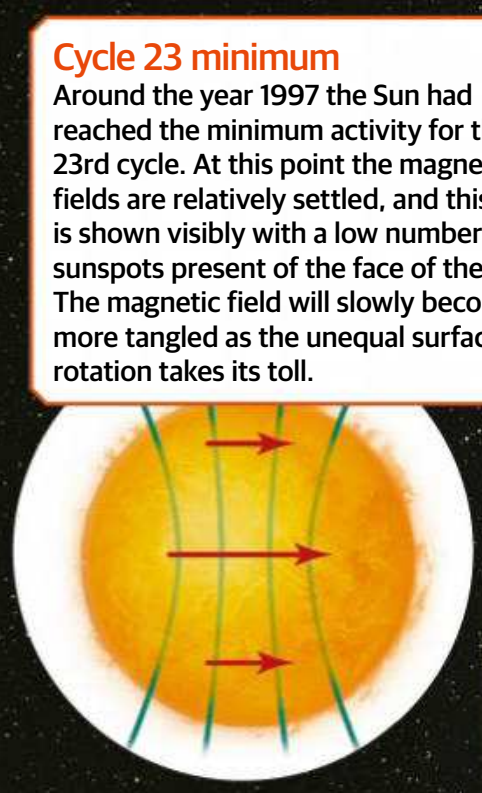
This 11-year cycle turns the Sun from a quiet ball of gas to a raging bull permeating the Solar System. **All About Space** gets an expert to explain why

Sunspots, flares, the Sun's hot corona and chromosphere, the solar wind and the Earth's aurorae all result from magnetic fields generated by a dynamo operating inside the Sun. The dynamo is cyclic, with a solar cycle period of about 11 years. To understand the cycle we adopt a strategy similar to crime detectives, but instead of 'follow the money', we follow the energy. Our story begins in the solar core where nuclear fusion converts hydrogen to helium, releasing energy and heating the core to about 15 million degrees Kelvin. This energy is carried outwards by radiation for the first 70 per cent of the distance to the surface, after which it is carried by convective motions. These convective motions are driven by the temperature difference; because the viscosity inside the Sun is very low, the motions are turbulent.

The convective motions interact with the rotation of the Sun, which rotates once per 25 days at its equator. Importantly this interaction between the small-scale convective motions and the large-scale rotation leads to large-scale stresses and causes the poles to rotate slower than the equator at a rate of about once every 33.5 days.

To understand the solar dynamo we can think of a piece of string - a magnetic field line - threading from the north pole of the Sun through the convecting region to the south pole. The piece of string at the poles will rotate once every 33.5 days, however, the piece of string near the equator will rotate once every 25 days, and the string will, over the course of several years, get wound up. This winding up is half of the dynamo process.

The second half happens when the field becomes sufficiently strong to erupt to the surface. During the eruption process the rising flux tube is affected by the rotation of the Sun due to the Coriolis force, and undergoes a 'tilt' so that it emerges with a small north-south separation between its positive and negative magnetic polarity. The combined north-south separation from many active regions builds up over an additional several years to create a new polar field with the opposite polarity to that which was originally there. This is one solar cycle, which lasts for about 11 years.



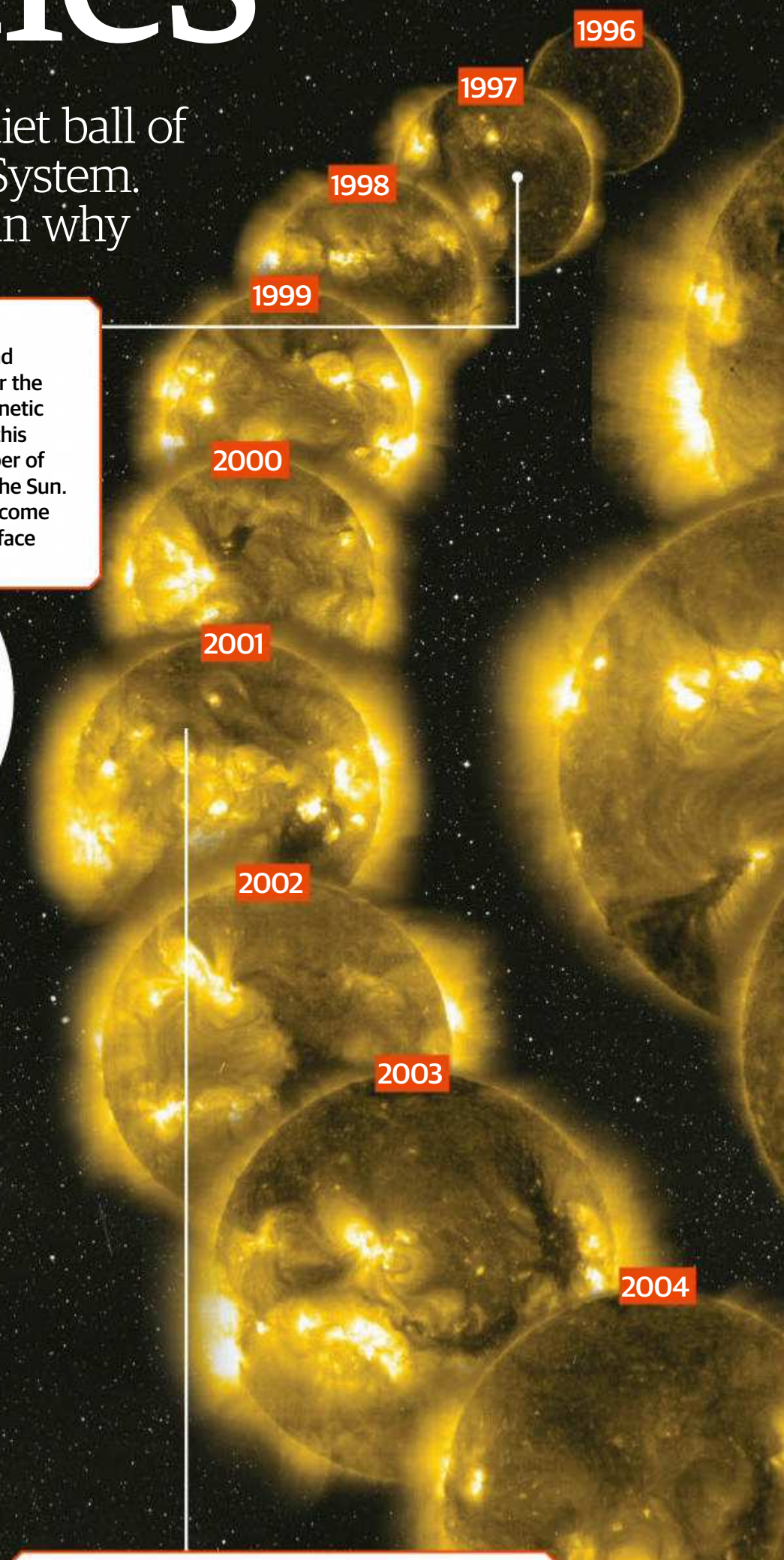
Cycle 23 minimum

Around the year 1997 the Sun had reached the minimum activity for the 23rd cycle. At this point the magnetic fields are relatively settled, and this is shown visibly with a low number of sunspots present of the face of the Sun. The magnetic field will slowly become more tangled as the unequal surface rotation takes its toll.



BIO
Dr. Robert Cameron

Cameron works at the Max Planck Institute for Solar System Research, situated in Göttingen, Germany, and specialises in understanding the strange activity of the Sun. His work studying the Sun's sunspots, subsurface flows and solar cycles makes him well equipped to explain this 11-year enigma.

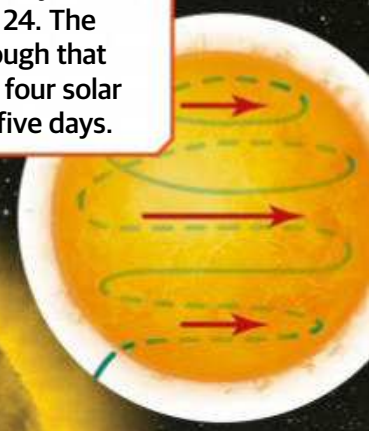


Cycle 23 maximum

The maximum sunspot activity for cycle 23, around the year 2001, was far greater than its succeeding cycle, which is a strong indication that the field lines are at their most tangled. This will subsequently cause more sunspots and more solar activity, for example more Coronal Mass Ejections (CME) will occur and the Sun will eject more highly energetic particles, powering Earth's aurora and creating a marvellous spectacle.

Cycle 24 maximum

Around the year 2014 cycle 24 had reached its cycle maximum. As mentioned of the cycle 23 maximum, the maximum of cycle 23 was much more intense than cycle 24. The magnetic field became uneven enough that in October of that year, there were four solar flares released just in the space of five days.



Cycle 24 minimum

Once again the Sun's activity dies down as the field lines reach a more harmonious status. In 2008 the Sun was extremely inactive with the lowest monthly count in December 2008 where only two sunspots were recorded with extremely low intensity, along with slow and less-dense solar wind activity.

© NASA/ESA, Nicholas Forder



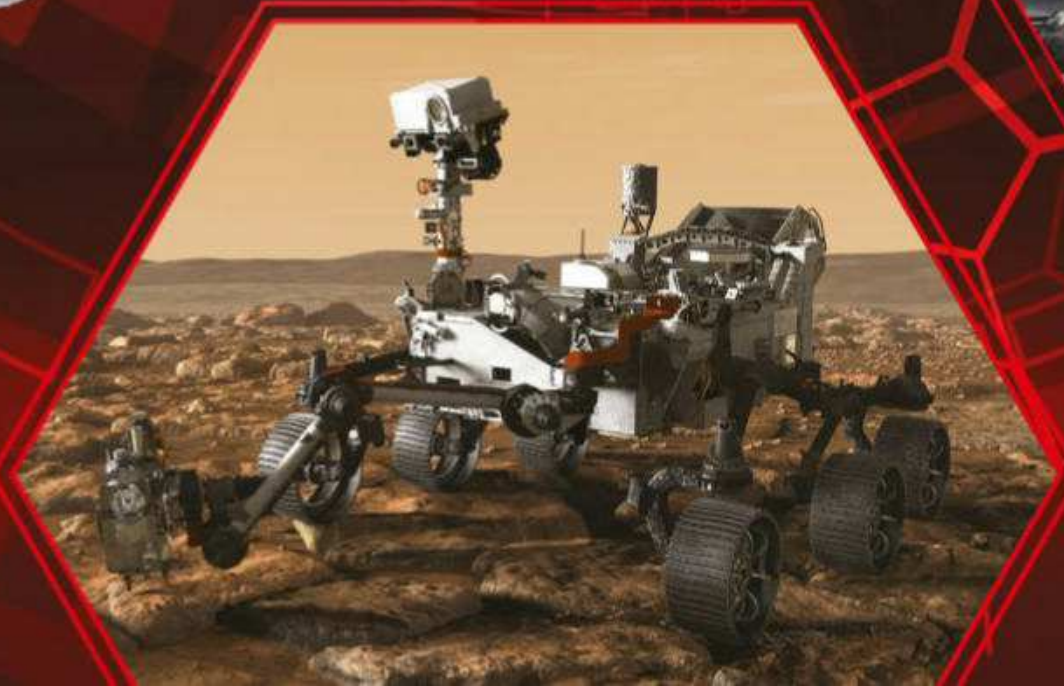


WELCOME TO THE FUTURE

All About Space looks at the science fiction technologies that have become a reality, and how they have revolutionised our exploration of the universe

Written by Lee Cavendish







STAR TREK: THE ORIGINAL SERIES

Release date: 1966 **Created by:** Gene Roddenberry

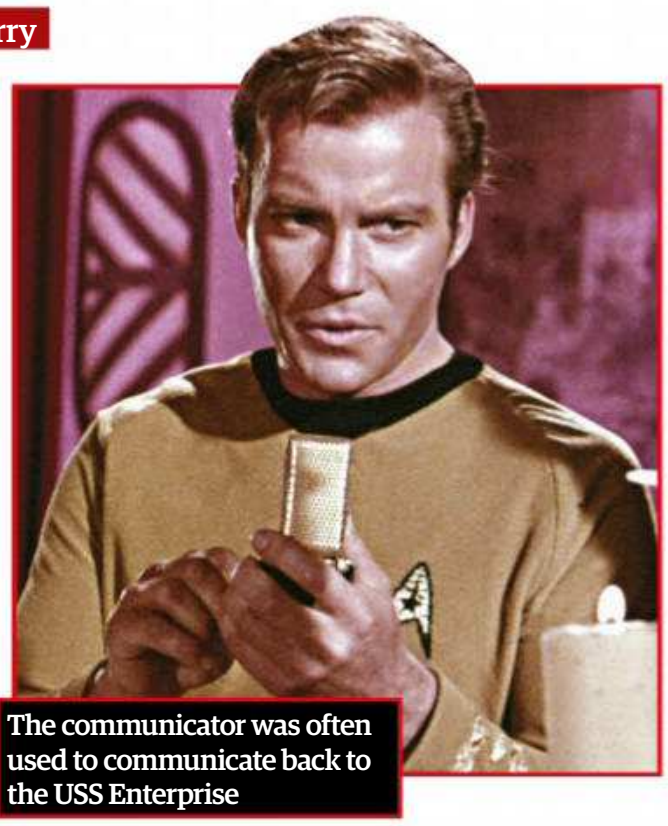
The mobile phone

Something that everyone has in their pocket, mobile phones have become a necessity in modern life with a plethora of features. It's unbelievable to think how far they have come since their initial invention in 1973.

The first mobile phone was a bulky, hefty phone that weighed 1.1 kilograms (2.4 pounds) and had a talk time of about 35 minutes. This was the Motorola DynaTAC, and at the time it would have cost thousands of pounds. The Motorola DynaTAC was invented by Martin Cooper, who led a team that created the first mobile phone in just 90 days.

A long-standing rumour was that Cooper got his inspiration from an episode of *Star Trek* in which Captain Kirk (William Shatner) used his communicator, a hand-held communications device. However, Cooper stated in an interview in 2015 that the original inspiration was from a comic strip called Dick Tracy, in which the character used a 'wrist two-way radio'.

Although this may not have been the original inspiration, the fact that the mobile communication device appeared on television in 1967 in an episode from *Star Trek: The Original Series* (Series 2, Episode 5, The Apple) six years prior to the invention is remarkable.



The communicator was often used to communicate back to the USS Enterprise

"Mobile phones have become a necessity in modern life with a plethora of features"



Universal translator



Language barriers no longer being an issue would revolutionise real-time communication. This idea is now becoming a reality with two-way language translator devices and software.

Star Trek: The Original Series aired between 1966 and 1969 and featured a host of technologies that were considered 'alien', as the show was set in the 23rd century. While exploring space, characters such as Captain Kirk and Spock (Leonard Nimoy) would come across alien life with their own language. The universal communicator was first seen on screen as Spock tampered with it in order to communicate with a non-biological entity (Series 2 Episode 9, Metamorphosis).

Although the idea here was communicating with an alien, a device capable of taking a person's native language and translating it to the user's language for conversational benefit is no longer science fiction. With products such as Sourcenext's Pocketalk, Google's Pixel Buds and Skype's new voice translation service, the technology has now caught up to the idea that a language can be identified, broken down and translated into the language of the user for real-time voice communication.

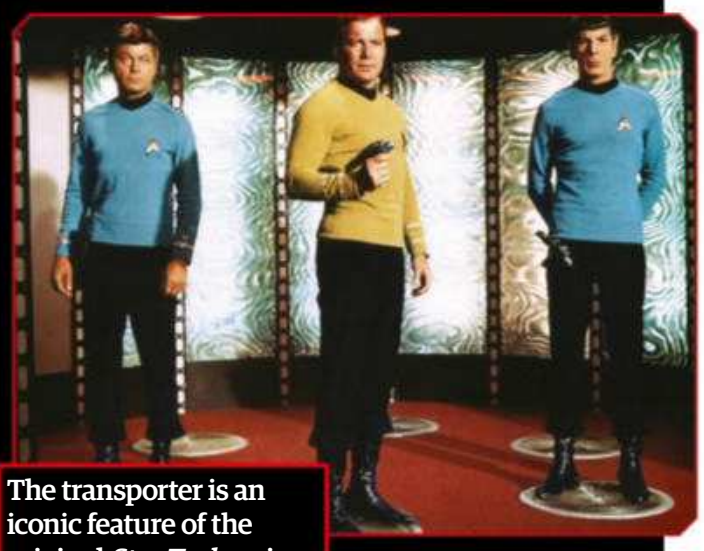


Star Trek **characters would often come across alien life with different languages**

Teleportation

The idea behind 'beaming' someone up was that a person could be broken down into an energy form, referred to as dematerialisation, and then converted back into matter at their destination, also referred to as rematerialisation. Transporting people onto the USS Enterprise has been around since the very beginning of the *Star Trek* series, with the transporter featuring in the pilot episode of *Star Trek: The Original Series*, The Cage.

Scientists can currently teleport balls of energy known as photons. It is not the same mechanism used in *Star Trek*; teleportation in this case is based on a quantum mechanics phenomenon known as 'quantum entanglement'. Scientists can create two photons with unknown states, also known as being entangled, which can be shot off in different directions. Once one photon has its state revealed, the other one simultaneously switches into the opposite state, regardless of distance. This information given to the other photon in order to change state happens at least 10,000 times faster than the speed of light.



The transporter is an iconic feature of the original ***Star Trek*** **series**

© Paramount Pictures/CBS Studios/ Everett Collection.;

STAR WARS

RELEASE DATE: 1977 & 1980 **DIRECTOR:** George Lucas & Irvin Kershner

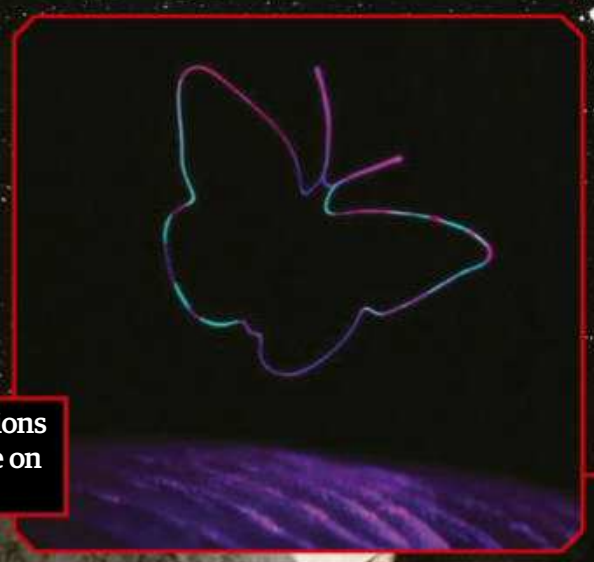
3D projections (holograms)

When *Star Wars: Episode IV – A New Hope* came out in 1977 it captured the imagination of millions of people and became extremely popular not just because of its storyline, but also for its intergalactic technologies. From a Death Star to a lightsaber, it seems many of these ideas rest on the cusp between actual physics and science fiction.

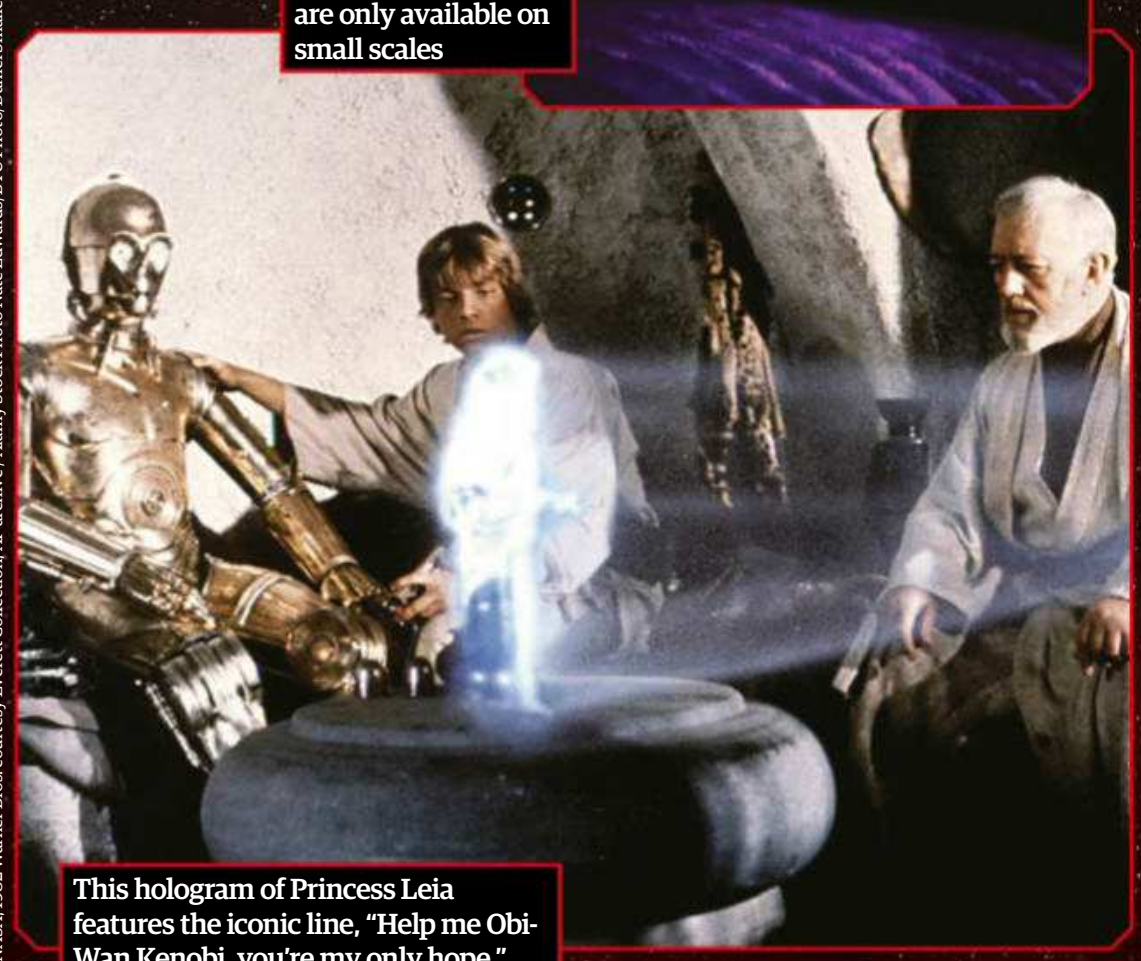
Not long into the film, Obi-Wan Kenobi (Sir Alec Guinness) receives a message, and not just any message, a holographic message. By definition, a hologram is a three-dimensional image created from the interference of light beams from a laser onto a two-dimensional surface, and can only be seen in one angle. What researchers from the Brigham Young University in Provo, Utah, United States, have now done tops that. They have been able to create a 3D image that can be seen from any angle.

This technique, called volumetric display, works more like an Etch A Sketch, but uses particles at high speeds. By using lasers, these researchers can trap a particle and move its position into the designated shape while a second set of lasers emit red, green and blue light onto the particle. The particle moves faster than our eyes can perceive, meaning that whatever image they create appears as though it is a solid line. If the image changes quickly enough, it appears to move.

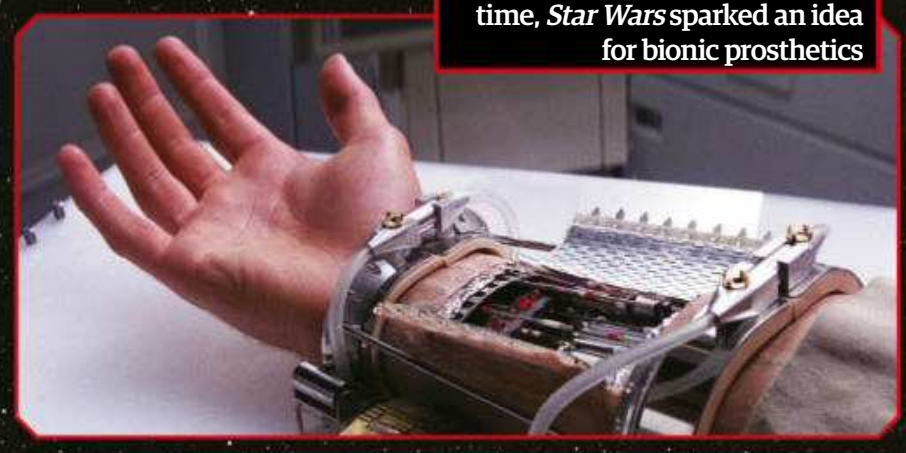
The current limitations are that this can only happen on extremely small scales. In fact, the image these researchers can project can rest on the tip of your finger. In order to produce a larger-scale image, or even produce complex moving images like a video recording, researchers need to find a way to control many particles simultaneously and speed up their movements. Perhaps sometime in the future, everyone will be able send an intergalactic plea for help.



These 3D projections are only available on small scales



This hologram of Princess Leia features the iconic line, "Help me Obi-Wan Kenobi, you're my only hope."



Even though using prosthetics had been common for a long time, *Star Wars* sparked an idea for bionic prosthetics

Bionic limbs

Imagine getting your hand chopped off by your own father and falling to the bottom of a floating building to then have your long-lost sister come and pick you up. That's a scenario that is very unlikely to happen – but not to say impossible. In *Star Wars: Episode V – The Empire Strikes Back* Luke Skywalker (Mark Hamill) receives a bionic hand by this exact means which has all the functions of a normal hand – this is an idea that is now more feasible than the previous scenario.

Researchers from the Georgia Institute of Technology in Atlanta, United States, have been developing a way for amputees to control each of their prosthetic fingers using an ultrasonic sensor. This technology provides incredibly accurate hand movements, and even allowed amputee Jason Barnes to play the piano again after his accident in 2012.

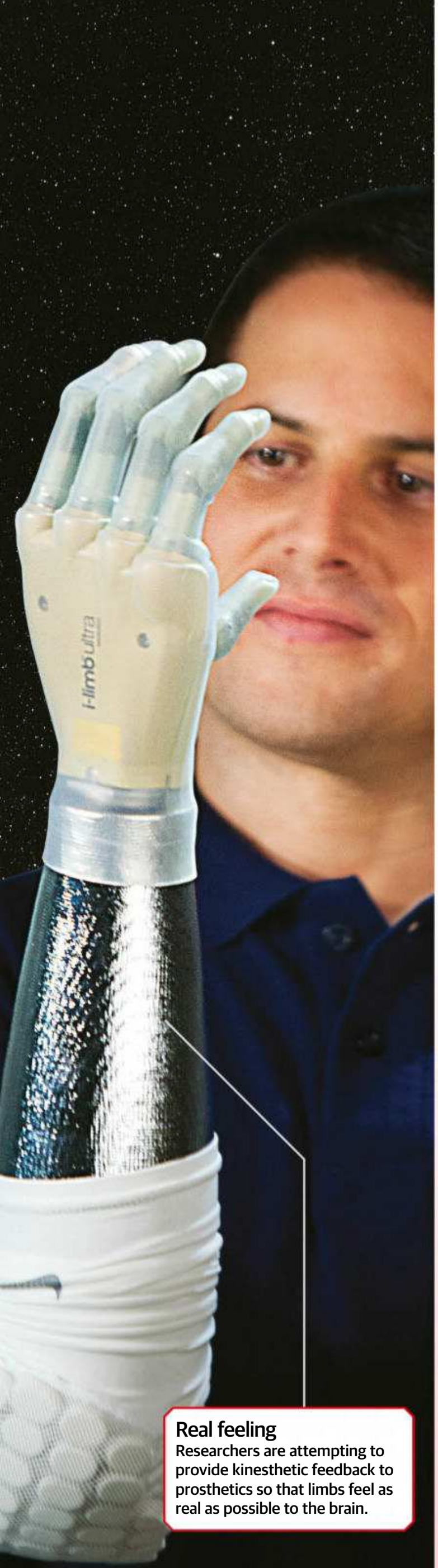
His current prosthesis uses electromyogram (EMG) sensors attached to his muscles which can be switched into different modes using different buttons on the arm and are controlled by the flexing or contracting of his muscles. This new prosthesis, however, uses machine learning and ultrasound signals to detect finer finger-by-finger movement.

This new technology is fantastic in that it will improve the quality of many people's lives and bring back old joys, such as Jason Barnes playing the piano. It's amazing to think that this is technology people saw almost 40 years ago on screen brought to life.

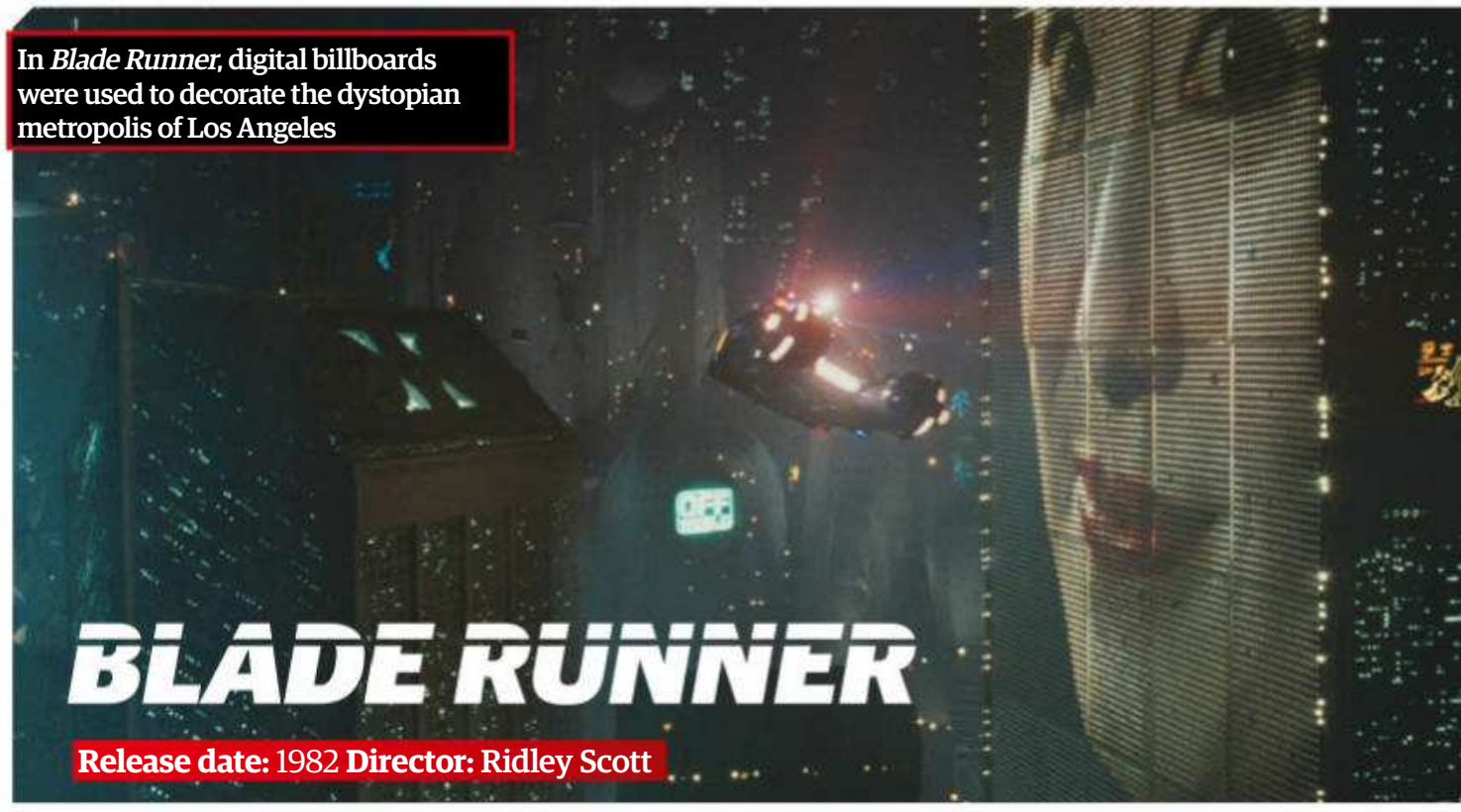


This *Star Wars*-inspired technology has provided Jason Barnes with the opportunity to play the piano again

© NASA; 1982 Warner Bros. courtesy Everett Collection; AF archive / Alamy Stock Photo Nate Edwards/BYU Photo/Daniel Smalley Lab; Georgia Tech;BSIP / Getty; Disney/Lucasfilm



Real feeling
Researchers are attempting to provide kinesthetic feedback to prosthetics so that limbs feel as real as possible to the brain.



In *Blade Runner*, digital billboards were used to decorate the dystopian metropolis of Los Angeles

Release date: 1982 **Director:** Ridley Scott

Digital billboards

More of a background technology than an aspect that plays a major role in the film, digital billboards made an appearance in *Blade Runner*. Director Ridley Scott presents a landscape shot of futuristic Los Angeles. While scanning the skyscrapers, a huge, digital, almost-cinematic billboard appears on one of the buildings.

This pre-internet concept sparked inspiration for the CEO of **DOOH.com**, Andrew Phipps Newman. DOOH – which stands for Digital Out Of Home – is a company dedicated to providing live, dynamic advertisements. This company is now at the forefront of advertising as it offers a more enticing form, one that will make people stop and stare.

These digital billboards have come a long way in recent years and have taken advantage of crowded cities, such as London and New York, to utilise this unique advertising tactic. It is incredible to think that this has come from an idea that was shown as a background feature of a neo-noir science-fiction film in the early 1980s.

This also begs to think, what other hidden gems that were in the more recent *Blade Runner 2049* film could spark, or have already sparked, a revolution in a completely different industry? And who knows, with the increase in space commercialisation, what digital billboards for space exploration could people be seeing in Times Square?

Artificial intelligence

Blade Runner heavily revolves around the idea of synthetic humans. In order to have synthetic humans, artificial intelligence must play an equally strong role. Artificial intelligence (AI) and its applications have split opinion. Many are worried about the potential fallout of giving computers intelligence, which has had disastrous consequences in many science-fiction works, although it hasn't come along the same way *Blade Runner*, which is set in the year 2019, predicted.

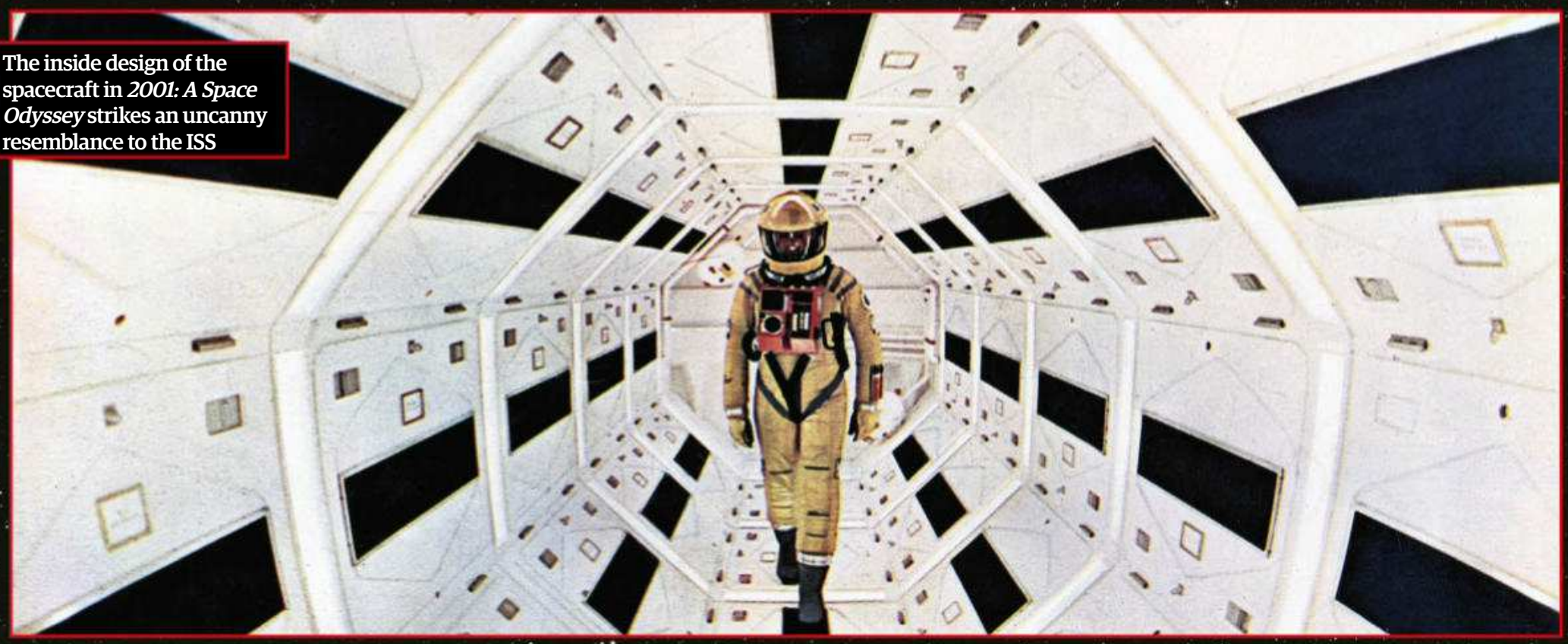
AI does have some very useful applications, however. For instance, astronomers have been training machines to find exoplanets by learning techniques and telltale signs while sifting through copious amounts of data collected by missions such as NASA's Kepler mission, and soon the recently launched TESS spacecraft.

However, some physicists, such as the late and great Professor Stephen Hawking, are opposed to AI. Hawking made it publicly clear that AI could be humanity's downfall if someone were to make it more advanced than our own species – a scenario scarily similar to the plot of this film. As for the time being, AI has not come along that far, and although robotics and AI is bound to improve in the future, its evolution will be heavily monitored.



Rick Deckard (Harrison Ford) can only distinguish the AI and real humans by a 'Voigt-Kampff' test





The inside design of the spacecraft in *2001: A Space Odyssey* strikes an uncanny resemblance to the ISS

2001: A SPACE ODYSSEY

Release date: 1968 **Director:** Stanley Kubrik

Space stations

Orbiting Earth in *2001: A Space Odyssey* is the 'Space Station V', a large, international space station. Does this sound familiar?

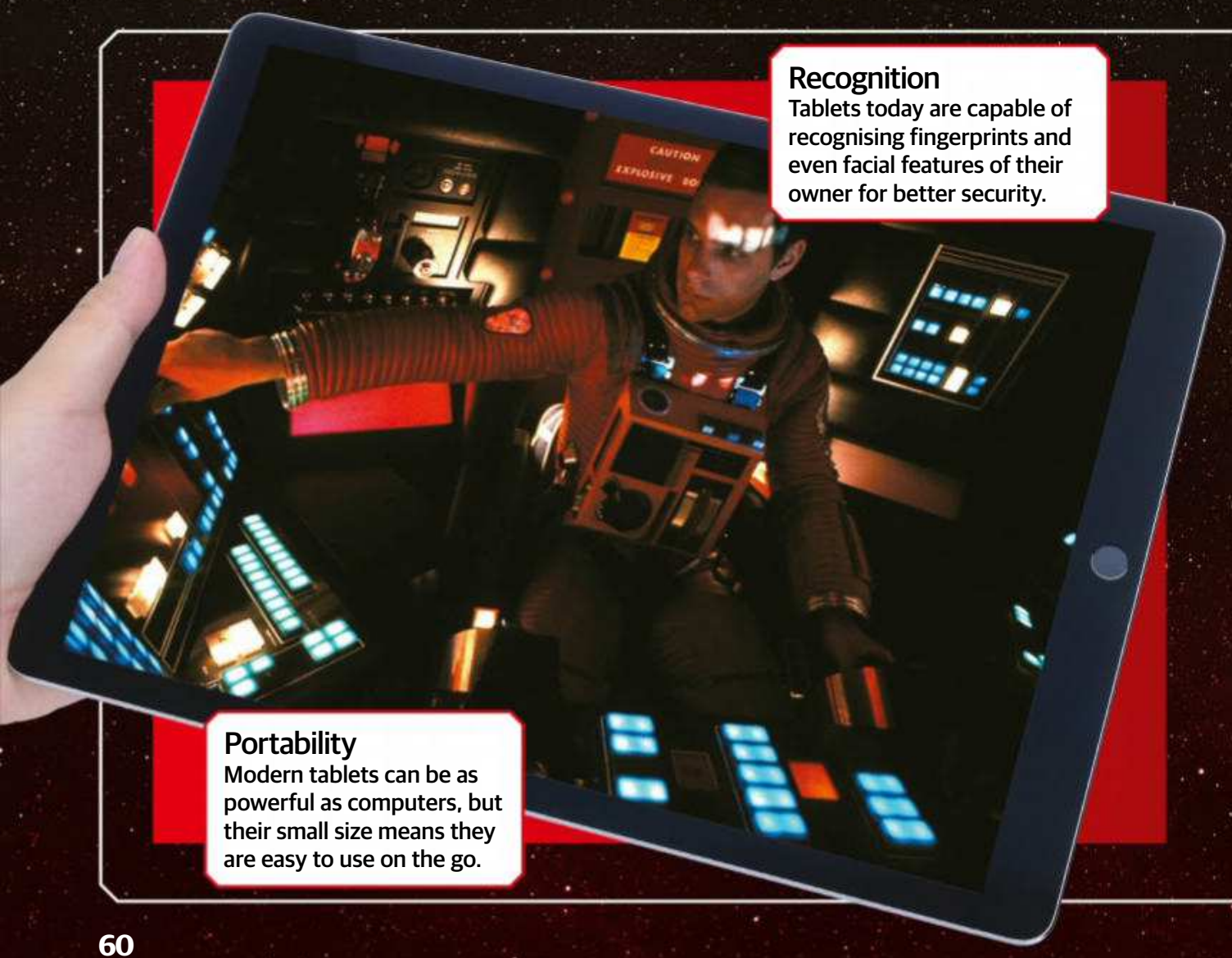
This sounds an awful lot like the International Space Station (ISS), which currently accommodates up to six astronauts from around the world at all times. Although the Space Station V is much more luxurious, the ISS has been fundamental to microgravity research since the start of its construction in 1998. The last of its components were installed 13 years later after many flights of the Space Shuttle program, which is a few years off the film's predictions for 2001.

The Space Station V wasn't just an out-of-this-world holiday experience, it was also utilised as a pit-stop before travelling to the Moon and other long-duration space destinations. This matches the intentions for the proposed Deep Space Gateway.

Long-duration spaceflight hasn't become as common as predicted in the 1960s due to our current knowledge of cosmic radiation and the mechanical requirements for such journeys. However, plans for a long-duration journey to Mars are coming ever closer to fruition, and the Deep Space Gateway could provide a valuable pit-stop for any future expeditions to the Moon and Mars.



Space station evolution has led to the glorious ISS, which holds six astronauts around the clock



Recognition
Tablets today are capable of recognising fingerprints and even facial features of their owner for better security.

Portability
Modern tablets can be as powerful as computers, but their small size means they are easy to use on the go.

Tablets

Tablets are wonderful handheld computers that can be controlled at the press of a finger. These handy devices are used by people across the globe, and even further upwards on the International Space Station.

Apple claims to have invented the tablet with the release of its iPad. However, Samsung made an extremely interesting case in court that it didn't: Stanley Kubrick and Sir Arthur C. Clarke did in the sci-fi classic *2001: A Space Odyssey*, a space-exploration film released in 1968.

This film is renowned for being ahead of its time, with its depictions of space travel and imagery being surprisingly accurate. In the film, Dr David Bowman (Keir Dullea) and Dr Frank Poole (Gary Lockwood) watch news updates from their flat-screen computers, referred to in the film as 'newspads'.

Samsung claimed that these 'newspads' were the original tablet; the made-up technology that featured in a film over 40 years before the first iPad arrived in 2010.

BACK TO THE FUTURE PART II

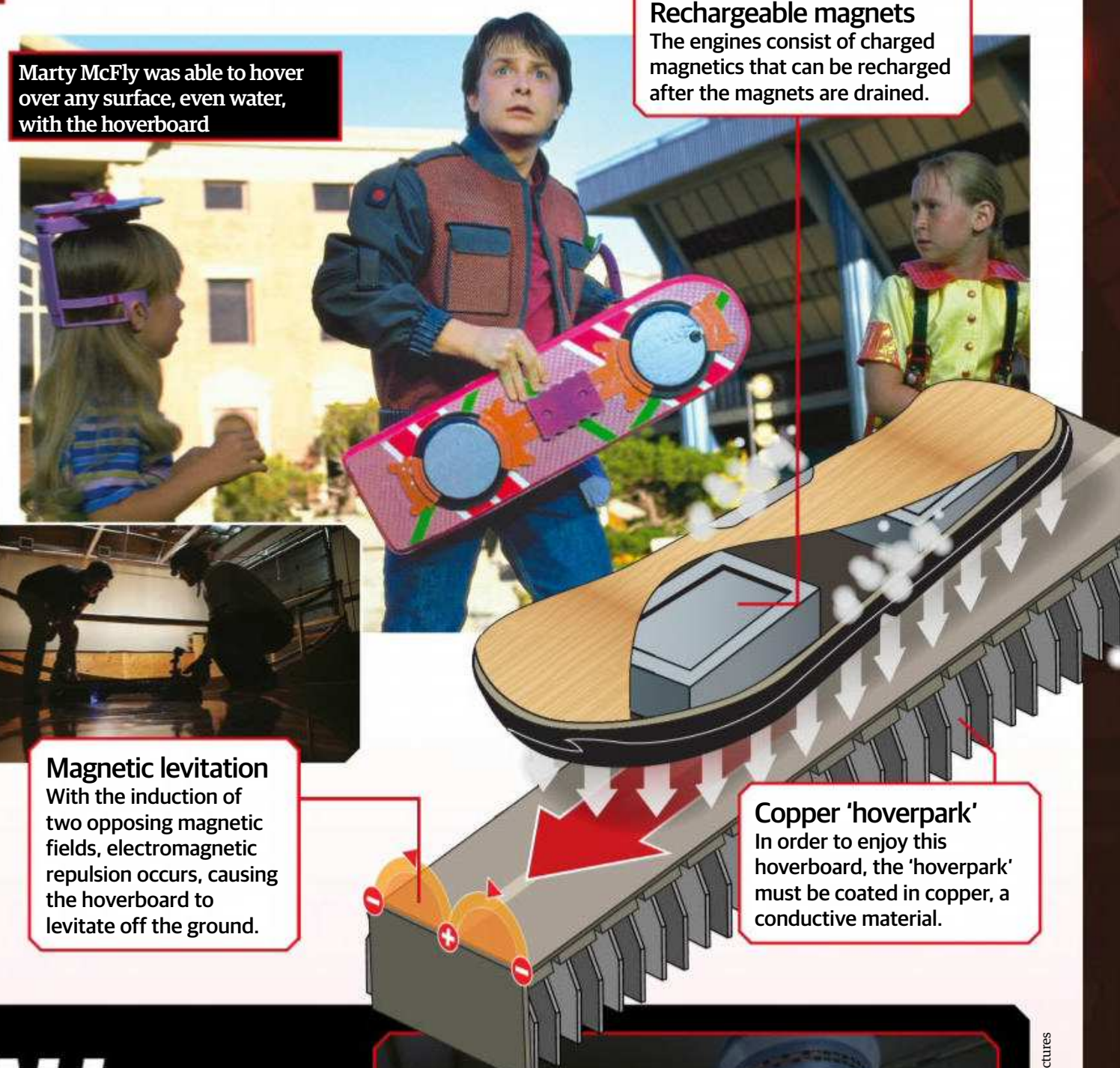
Release date: 1989 **Director:** Robert Zemeckis

Hoverboards

The *Back to the Future* trilogy is a highly enjoyable trio of time-travelling adventures, but it is *Part II* that presents the creators' vision of 2015. However, *Back to the Future* predicted a far more outlandish 2015 than what actually happened just three years ago. One correct prediction about 2015 is the presence of hoverboards, like the one Marty McFly (Michael J. Fox) 'borrows' to make a quick escape.

Although they aren't as widespread as the film perceives, hoverboards actually exist. The first real one was created in 2015 by Arx Pax, a company based in California, United States. The company invented the Magnetic Field Architecture (MFA™) used to provide the levitation of a hoverboard. To explain how this works as simply as possible, it means that the board generates a magnetic field, which in turn creates an eddy current. That then creates another opposing magnetic field. These magnetic fields repel each other which provides lift.

This is an amazing achievement in bringing a completely fictional idea from a film first aired in 1989 to reality. This work has even gone so far as to be recognised by NASA, who in the same year of 2015 entered into a Space Act Agreement to use the same MFA™ technology to create 'micro-satellite capturing devices', allowing them to manipulate CubeSats.



Marty McFly was able to hover over any surface, even water, with the hoverboard

Rechargeable magnets
The engines consist of charged magnetics that can be recharged after the magnets are drained.

Magnetic levitation
With the induction of two opposing magnetic fields, electromagnetic repulsion occurs, causing the hoverboard to levitate off the ground.

Copper 'hoverpark'
In order to enjoy this hoverboard, the 'hoverpark' must be coated in copper, a conductive material.

TOTAL RECALL

Release date: 1990 **Director:** Paul Verhoeven

Driverless cars

In the 1990 film *Total Recall* main protagonist Douglas Quaid (Arnold Schwarzenegger) finds himself in the middle of a science-fiction showdown on Mars. The film is set in the year 2084, which could be an accurate prediction with major space agencies such as NASA and SpaceX stating their intentions to colonise Mars in the near future.

In one scene Quaid is on the run from the bad guys and jumps into a car, but this isn't just any old car – this is a car from 2084. In the front of the car is a robot that introduces the vehicle as "Johnny Cab", inferring that this is a driverless car and all the on-board computer system needs is an address to take it to its intended destination.

Although the driverless car wasn't seen in action before the protagonist yells profanities and takes over driving it himself, the idea of having a car that takes you to your destination using its onboard satellite navigation has become increasingly popular.

SpaceX's sister company Tesla has since produced driverless cars, and NASA last year stated its intentions to help in the production of driverless cars, as they would improve the technologies of robotic vehicles on extraterrestrial surfaces such as the Moon or Mars.



Johnny Cab wasn't able to move unless he had the destination, ultimately leading to his demise



Developing autonomous driving would improve the efficiency and safety of future rovers

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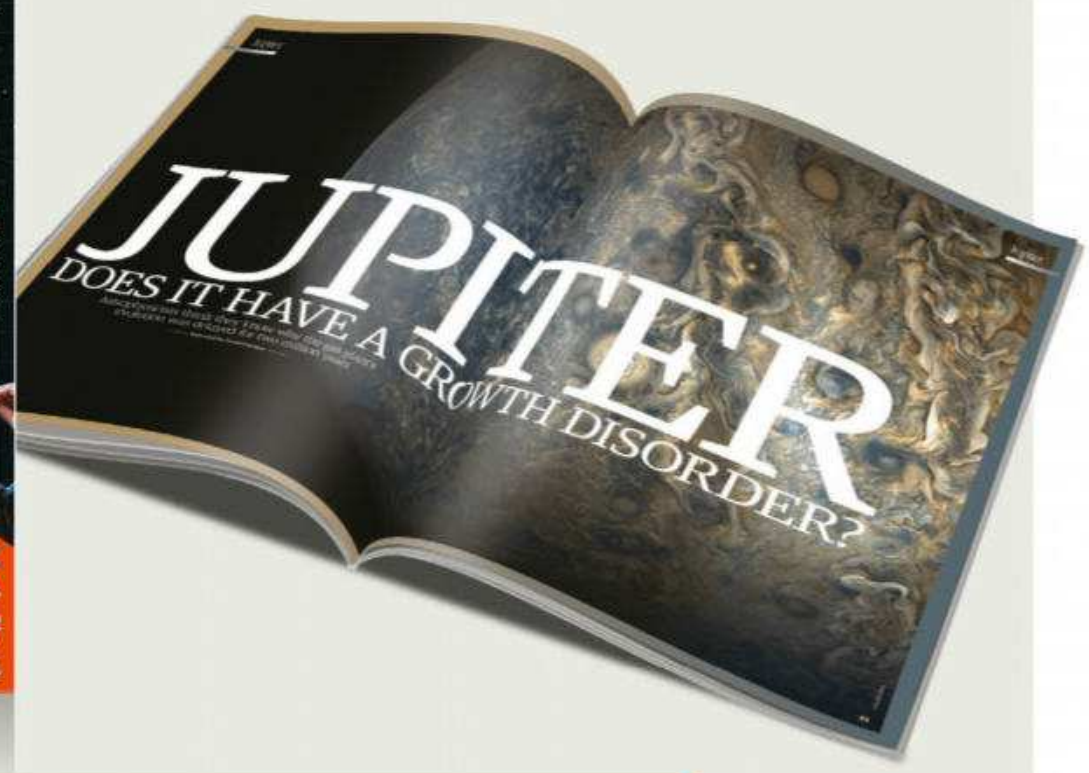
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With observing season officially here, these guides will assist with your tours of the night sky - whether you're a beginner or seasoned astronomer

Reference guide

Stargazing: Beginners Guide to Astronomy

Cost: £9.99

Offering complete advice from the ground up, *Stargazing* is the perfect manual for beginners to astronomy, introducing the world of telescopes, planets, stars, dark skies and celestial maps. Discover how to tackle light pollution, how to stargaze with just your eyes, and what equipment is best for beginners.

Astronomy experts Radmila Topalovic and Tom Kerss explain the best ways to plan your stargazing experience and the key things to look out for on specific dates throughout the year. With seasonal star charts, constellation charts and facts about our Solar System, *Stargazing* is packed full of useful information and guidance for both the Northern and Southern Hemispheres.

Bridging the gap between human curiosity and the need for scientific expertise, *Stargazing* allows a complete novice to understand our place in the cosmos and enjoy the beautiful and extraordinary wonders of the night sky. The perfect companion to the best-selling *Guide to the Night Sky* from Collins, *Stargazing* is a great way to get started in the fascinating world of astronomy.



Observing aid

Collins Planisphere

Cost: £9.99

A star finder that allows visible stars to be identified for any date and time for locations in the Northern Hemisphere, compiled by astronomical experts Storm Dunlop and Wil Tirion and approved by the astronomers of the Royal Observatory Greenwich.

It features an easy-to-use practical tool to help any astronomer identify the constellations and stars every day of the year. Just dial in the date and time by rotating the inner plastic disc showing the time until it lines up with the relevant day of the year on the outer ring. The part of the sky appearing on the planisphere shows the arrangement of the stars above you.

This star chart is suitable for use anywhere in Britain and Ireland, Northern Europe, Canada and the northern USA. Best viewed as near to latitude 50 degrees north as possible, the moveable disc also comes in a plastic wallet which contains further information about stargazing.

Coffee table book

Astronomy Photographer of the Year: Collection 6

Cost: £25

All the winning and shortlisted images from the 2017 Insight Astronomy Photographer of the Year competition, hosted by the Royal Observatory, Greenwich, are featured in this stunning hardback. Royal Observatory Greenwich is the historic home of British astronomy, Greenwich Mean Time and the world-famous Meridian Line. Established in the 17th century, it was from here that the great scientists of the time precisely mapped the stars to help navigate at sea.

Centuries later, the Royal Observatory continues to be closely associated with global time zones, universal time and longitude. In the footsteps of the Astronomers Royal, our modern astronomers explore the past, present and future wonders of astronomy, space and the stars, taking you on amazing journeys to explore and experience the wonders of the night sky.

The images are submitted in one of the following categories: Earth and Space, Our Solar System, Deep Space, Young Astronomy Photographer of the Year as well as the Special Prize Categories: Best Newcomer, People and Space and Robotic Scope. Each image is accompanied by a caption and photographer, location and technical details.

"*Stargazing* is packed full of useful information and guidance"

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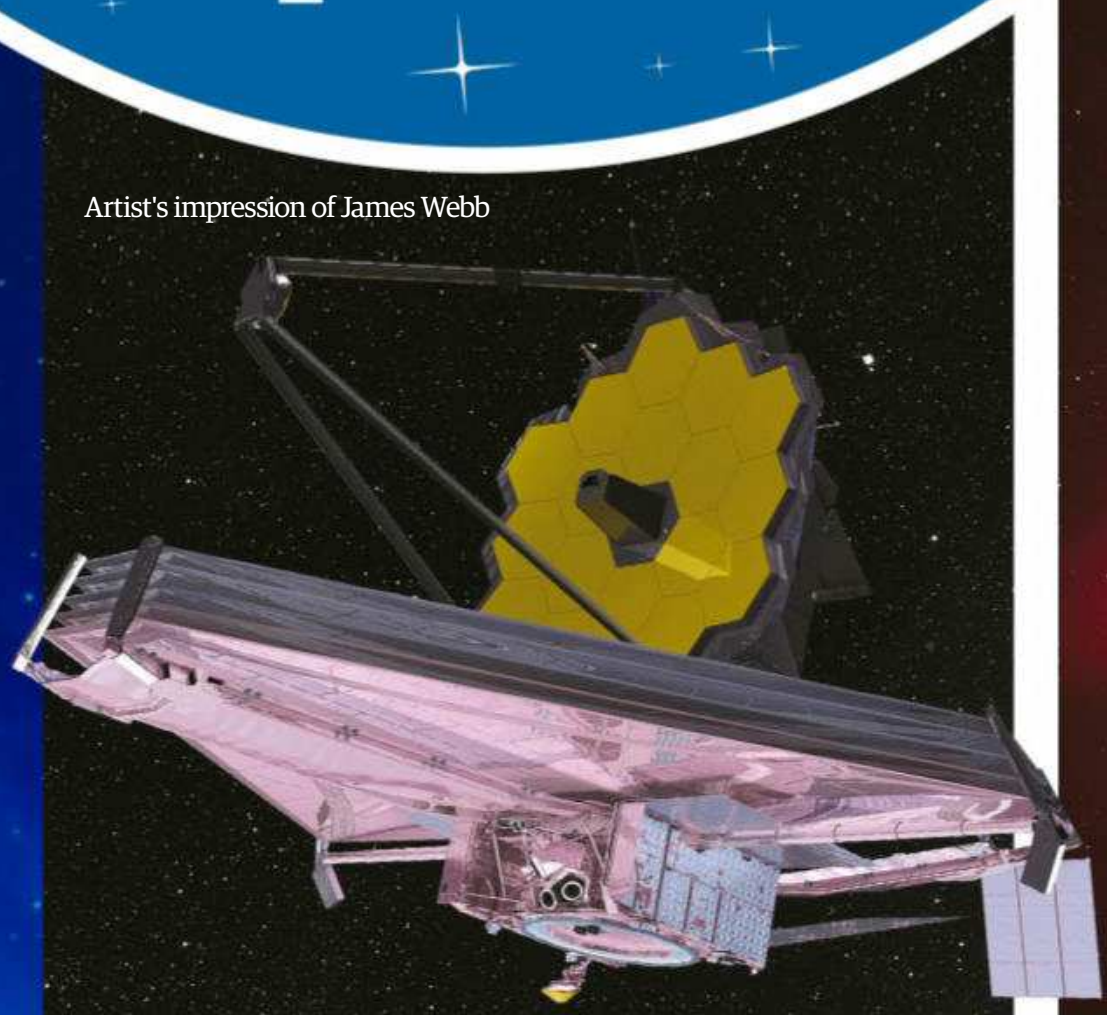
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Artist's impression of James Webb

SPACE EXPLORATION

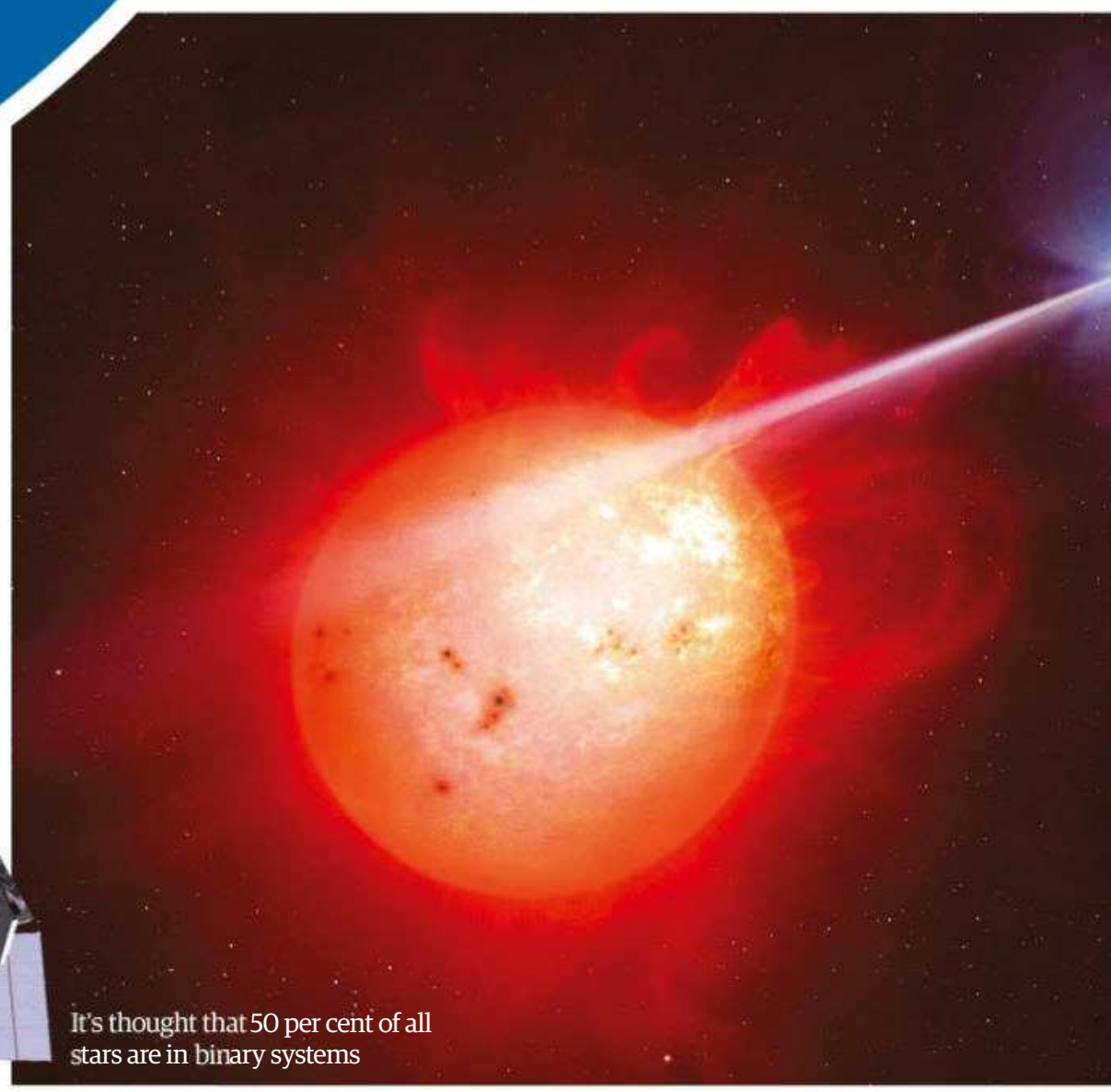
What telescope would we need to get high-resolution images of the planets?

Exoplanets have already been directly imaged orbiting the stars Fomalhaut and Beta Pictoris, as well as three exoplanets orbiting HR 8799. These planets are large Jupiter-sized bodies orbiting far from their host star and are observed with special instruments called coronagraphs that are used to block the starlight while leaving the planets visible.

In order to get a clear image of a possible habitable exoplanet, such as an Earth-analogue, the observation would need to be able to resolve the star from the planet and deal with the very large contrast in light between the two. To get a feel for these two difficult tasks, get a bright torch (flashlight) and a small marble. Have a friend stand across a room from you, hold the marble against the torch and shine the light directly into your eyes. Can you see the marble? Small, close-in exoplanets orbit very near in angle to their stars and shine very dimly by reflected light. Just building a big telescope alone will not allow the observation. Astronomers are working to make special telescopes such as the James Webb Space Telescope (JWST) and special instruments (star shades and vortex coronagraphs) that can be placed in space, above the disrupting effects of our atmosphere, in hopes of obtaining a direct image and measurement of an Earth-like planet, perhaps revealing signatures of life.



Dr Steve Howell is a senior research scientist at NASA's Ames Research Center



It's thought that 50 per cent of all stars are in binary systems

ASTROPHYSICS

How do we measure distances to space objects?

There are many methods to do this. Let me cite parallax, because we use it in our Gaia mission. For nearby - and not-so-nearby - stars we can exploit the fact that their position in the sky depends on our position as an observer. Much like near objects appear to move in front of background objects when you as an observer move, say, driving by a bunch of people in front of a landscape.

In astrometry we can use the fact that we move with the Earth around the Sun, so our observation position relative to the Sun changes by 2AU (approximately 300 million kilometres or 185 million miles) in six months. A star that moves by one second of arc (equal to 1/3600 of a degree) due to the change in our position by 1AU (the Earth-Sun distance) has a distance of 1 parsec (parallax second). One parsec is equal to 3.26156 light years, which is the distance light travels in 3.26156 years, and is equal to 30.9 billion kilometres (19.2 billion miles). With the Gaia spacecraft, for example, we can basically determine the distance of half of the Milky Way stars using this method.

For more distant objects, like other galaxies, we use 'standard candles'. Those are variable stars, the absolute brightness of which is correlated with the period of the variation. Knowing the variation, we can derive the absolute brightness. Knowing the absolute brightness and the apparent, measured brightness we can determine the distance. Even further objects, like quasars, are measured by looking at the redshift due to the cosmic expansion. The redshift is directly correlated to the distance, as discovered by Edwin Hubble.



Dr Markus Landgraf is a senior mission analyst at ESA

Make contact: @spaceanswers /AllAboutSpaceMagazine space@spaceanswers.com



ASTROPHYSICS

Why do most stars never form alone?

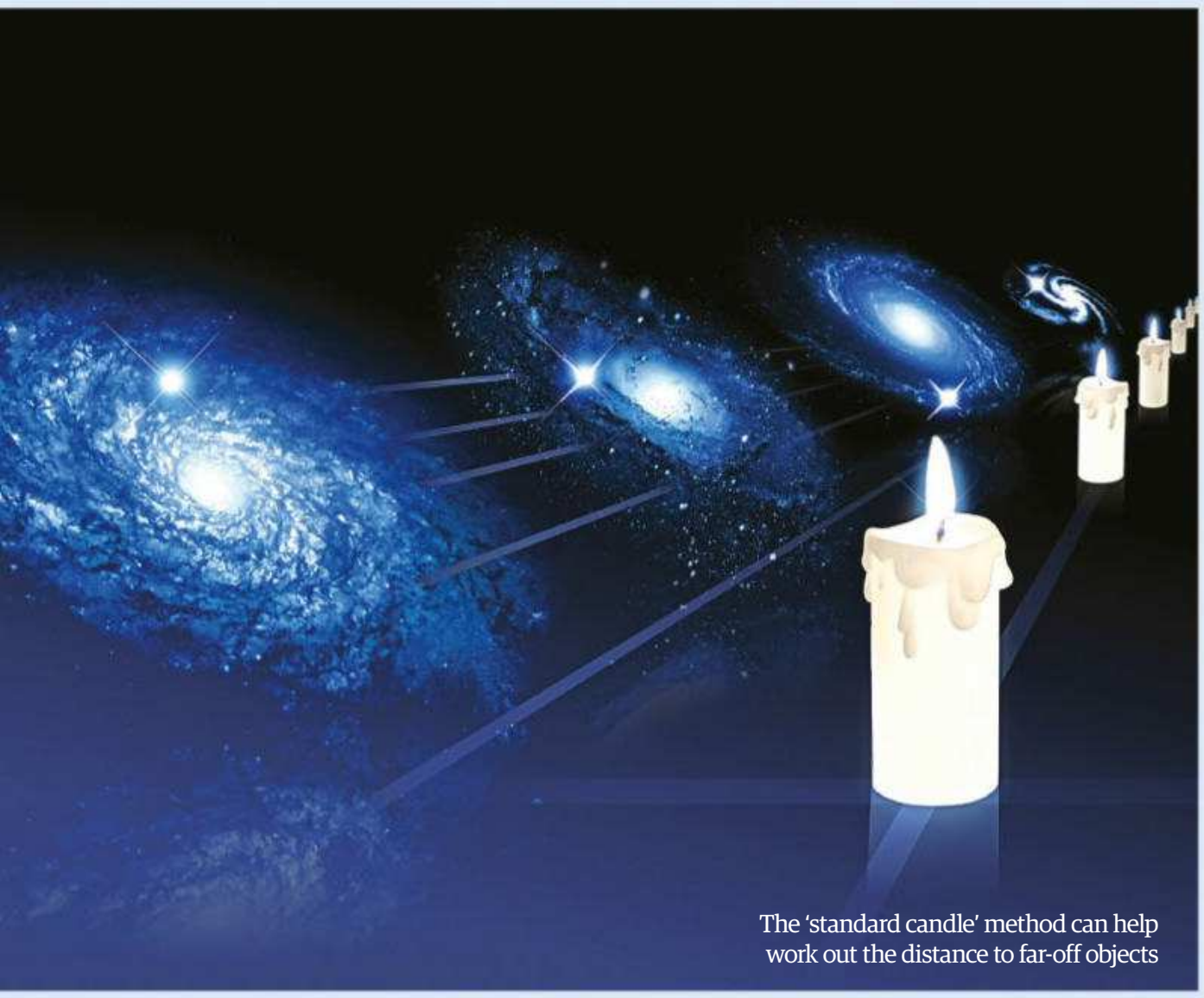
It is believed that maybe up to 50 per cent of all stars are in binary systems, with many researchers even suggesting that an even higher percentage of stars are born as binaries.

The high percentage of binary stars is closely linked to the way stars form. It is well established that most stars form in clusters rather than in isolation. In the dense parts of clusters such stars could pair up, forming binary stars. Another way that binaries can form is by the breaking up of discs around newly formed stars. These discs are a natural result of the star-formation process due to the initial rotation of the interstellar cloud that collapses to form a star. A disc increases in mass as more material from the cloud falls onto it and can become unstable or, in other words, it becomes too heavy to be maintained and fragments, breaking up into stars.

If fragmentation happens quickly after the first star has formed then the two stars may end up having similar masses. If it happens later on, the result will be a binary with two stars with unequal masses. The formation of more multiple star systems – triples, quadruples and so on – is also possible, and quite common. The study of binaries is important as their properties contain information about how stars form.



Dr Dimitris Stamatellos is a guild research fellow of Astrophysics at the Jeremiah Horrocks Institute, University of Central Lancs



The 'standard candle' method can help work out the distance to far-off objects

ASTROPHYSICS

Do white holes exist?

There is a possibility. Black holes, on the other hand, we know are out there for certain. These dark twins of white holes are like gravitational quicksand: they pull things towards them in the same way that all matter does, appearing to be nothing special, like quicksand. However, when you come too close you discover that the collected stuff has bent space and time so much that there is no escape.

If you can imagine the opposite of quicksand, a normal-looking patch of earth that lets nothing in, but can emit whatever it contains, you're on track to imagining a white hole. They also gravitationally attract but, unlike black holes, you can't get close. No matter what, things only come out of a white hole.

For much of the 20th century, physicists doubted the existence of black holes. Instead it turns out that black holes are more abundant and more varied than anyone could have guessed. The greatest black hole mystery may even tie black and white holes together: how do they end their lives? Recent ideas suggest that black holes could die by quantum mechanically metamorphosing into symmetrically exploding white holes. Through seeking signs of these explosions, we hope to learn whether white holes exist.



Professor Hal Haggard is an assistant professor at Bard College, New York

White holes are currently only theorised to exist

© NASA; ESA/J Mai; Tobias Roetsch; Peters & Zabransky; M. Garlick/University of Warwick/ESO



PLANETS

How will the Earth end?

I would say the most likely fate for Earth as we know it will come from within. Whether it is a nuclear war, mutated virus, climate catastrophe or collapse of civilisation, one only needs to look at history to see where the future may go. That's part of my reason for believing humanity should establish a second biosphere to safeguard civilisation, culture and technology from our mistakes, sort of like seed banks.

Those man-made collapses would still yield the most life-friendly planet in the Solar System. We have a long time until the Sun turns into a red giant and our oceans boil away. Hopefully we will be out of the Solar System by then. There is always the Jovian system that might be more habitable as the Sun gets bigger.

Long before the Sun starts to die, Earth will be impacted by a large asteroid or comet, perhaps at the same scale of the impact event 65 million years ago. But life even survived then, and Earth returned to a habitable state. Again, if we had a second biosphere, human civilisation could return to Earth once it was habitable.



Dr Patrick Troutman is a senior systems engineer at NASA's Langley Research Center

"Humanity should establish a second biosphere to safeguard civilisation, culture and technology from our mistakes"

© NASA; Tobias Roetsch;

Questions to... @spaceanswers /AllAboutSpaceMagazine space@spaceanswers.com

ASTROPHYSICS

How close would a supernova have to be to destroy life?

If a supernova was to go off within about 30 light years of us, that would lead to major effects on the Earth, possibly mass extinctions. X-rays and more energetic gamma rays from the supernova could destroy the ozone layer that protects us from solar ultraviolet rays. It could also ionise nitrogen and oxygen in the atmosphere, leading to the formation of large amounts of smog-like nitrous oxide in the atmosphere.

Supernovae happen about once every 100 years in the Milky Way. But the Milky Way is a big place, roughly 100,000 light years across. Given that, and the fact that the Sun is near the outskirts of the Milky Way where few stars massive enough to become supernovae are born, having a supernova within 30 light years of the Sun should, on average, happen only once in every 100 million years.



Dr Mark Reid is senior radio astronomer at the Harvard-Smithsonian Center for Astrophysics



The Crab Nebula (M1) is an ancient supernova remnant

HUNT FOR LIFE

Where's the most likely place to find life in the Solar System, other than Earth?

Astrobiologists regard Mars, Titan, Europa and Enceladus as possible habitable places in our Solar System. However, I think the best place for us to search for signs of alien life is in the rocks of Mars that are protected from the ionising radiation currently bombarding the surface. Finding signatures of ancient extraterrestrial microbial life and establishing confidence in that finding will largely depend on the quality of the preserved record. Radiation can seriously alter ancient biosignature records, especially organics, but to what extent and how remains elusive. The reality is that any chemical and physical alteration can complicate and lower our confidence in interpreting signs of ancient life. The same is true for interpreting ancient terrestrial biosignatures.

On Earth, life is ubiquitous – we find life in nearly every extreme environment. This tells us that microbes are incredibly adaptive. However, microbes don't always flourish in extreme environments. We find more diverse life where nutrients, food and energy sources are plentiful. On Mars, I think it is fair to assume that if life ever existed there, it would be very adaptive too. Over the eons, life may have learned to cope or even utilise ionising radiation by moving to shielded environments, such as the subsurface, and evolving biochemistry to repair damage to cells. In any case, the ionising radiation makes the top metre or so of surface rocks an extreme environment. If microbes adapted to living in these subsurface rocks, then they might flourish if there was a way for nutrients to circulate in the rocks. Perhaps the ExoMars mission will discover clues to the modern habitability of this more protected subsurface environment and if life is there.



Dr Jennifer Eigenbrode is an astrobiologist at NASA's Goddard Space Flight Center



Many missions are looking for signs of past life on Mars

STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

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What's in the sky?

11 OCT
Conjunction between the Moon and Jupiter in Libra


©Jj1z2

12 OCT
The Moon and Jupiter make a close approach,passing within 3°56' of each other in Libra

15 OCT
Conjunction between the Moon and Saturn in Sagittarius

15 OCT
The Moon and Saturn make a close approach, passing within 1°47' of each other in Sagittarius

16 OCT
Asteroid 136199 Eris is at opposition in Cetus


©ESO

18 OCT
Conjunction between the Moon and Mars in Capricornus


©Tunc Tezel

31 OCT
The Fornax dwarf spheroidal galaxy is well placed for observation in Fornax


©Marcin Stolarz

4 NOV
The Taurids reach their peak of ten meteors per hour

Red light friendly
In order to preserve your night vision, you should read our observing guide under red light



Jargon buster

Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

14 OCT
Conjunction between Venus and Mercury in Virgo


©Alexander Meleg

14 OCT
The Triangulum Galaxy (M33) is well placed for observation in Triangulum


©NASA

18 OCT
The Moon and Mars, pass within 1°54' of each other in Capricornus


© Anton Vakulenko

21 OCT
The Orionids reach their peak at a rate of 25 meteors per hour

24 OCT
Uranus is at opposition in Aries

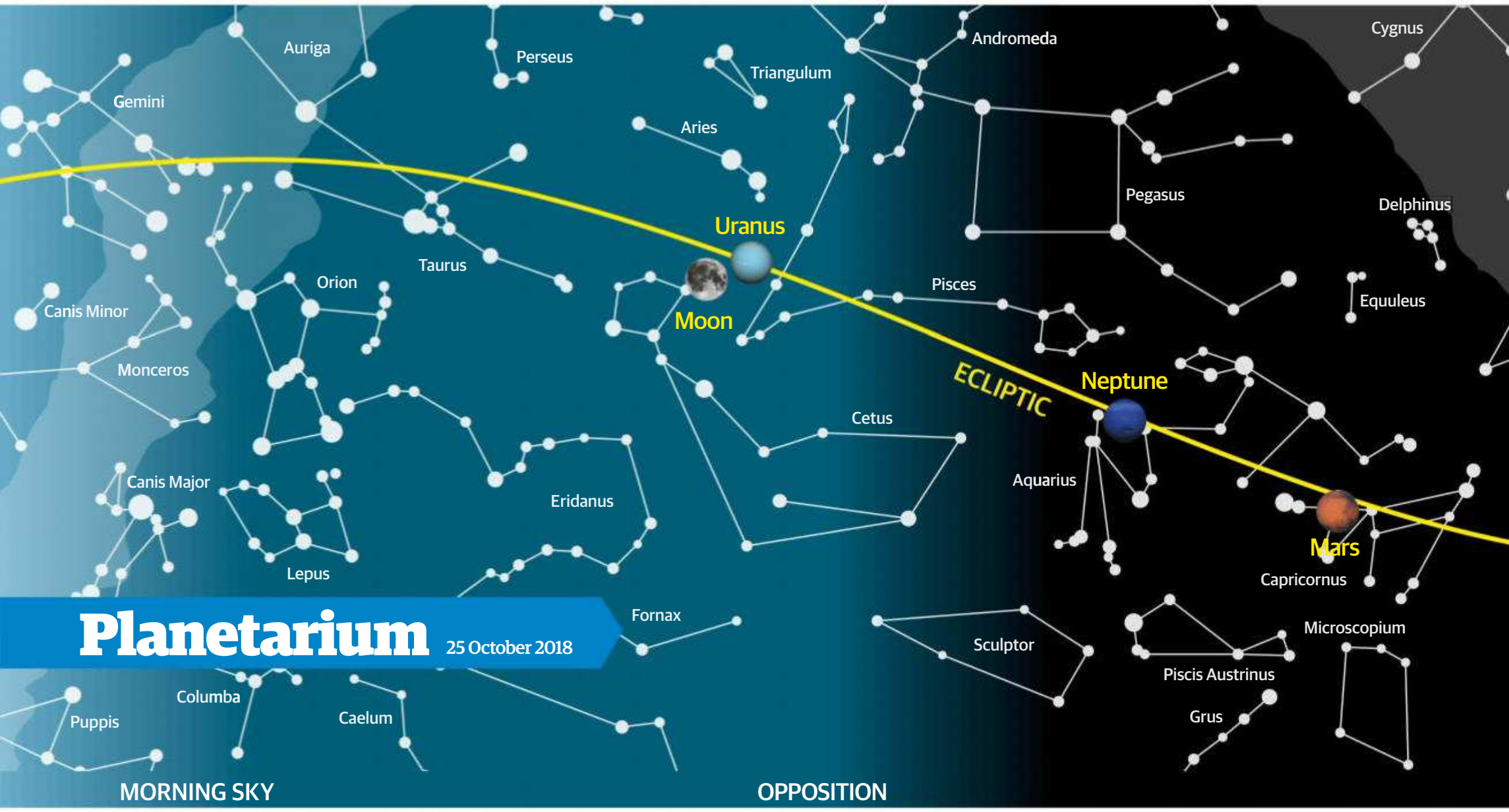
31 OCT
The Moon and M44 make a close approach, passing within 0°39 in Cancer

6 NOV
Conjunction between the Moon and Venus in Virgo


© Fernando de Gorocica

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

STARGAZER



Planetarium

25 October 2018

Moon calendar

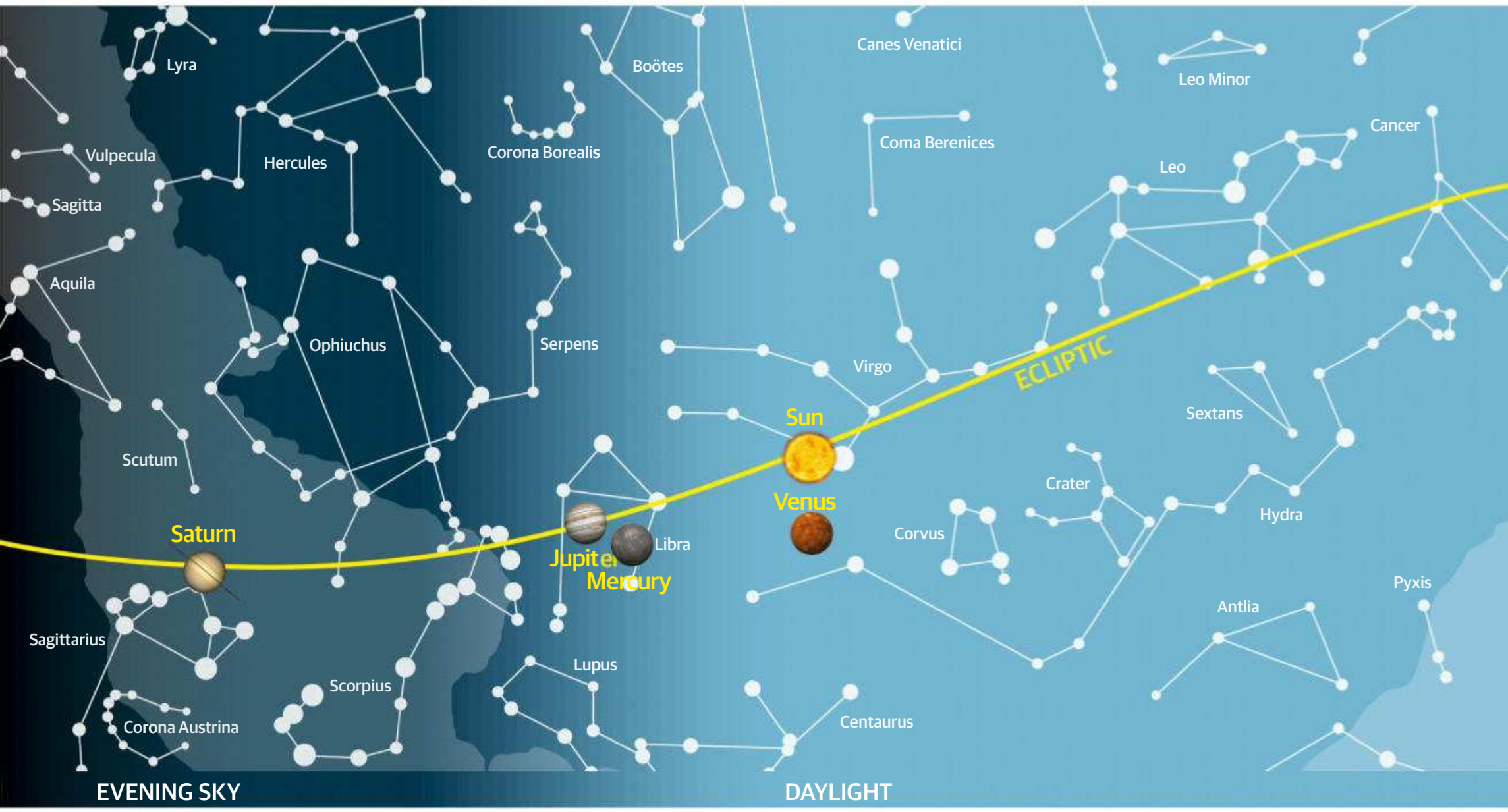
* The Moon does not pass meridian on 23 October

11 OCT 7.3% 09:44 19:50	**12 OCT** 13.8% 10:56 20:19	**13 OCT** 21.8% 12:03 20:54	**14 OCT** 30.8% 13:05 21:35			
15 OCT 40.4% 13:59 22:22	**16 OCT** FQ 50.1% 14:46 23:15	**17 OCT** 59.8% 15:25 --:--	**18 OCT** 69.1% 00:13 15:58	**19 OCT** 77.7% 01:15 16:26	**20 OCT** 85.4% 02:20 16:50	**21 OCT** 91.8% 03:26 17:12
22 OCT 96.5% 04:34 17:33	**23 OCT** --:--*% 05:44 17:54	**24 OCT** FM 99.2% 06:56 18:16	**25 OCT** 99.7% 08:09 18:41	**26 OCT** 97.7% 09:24 19:10	**27 OCT** 93.2% 10:39 19:45	**28 OCT** 86.4% 10:51 19:30
29 OCT 77.4% 11:56 20:24	**30 OCT** 66.9% 12:53 21:28	**31 OCT** LQ 55.4% 13:39 22:41	**1 NOV** 43.5% 14:17 23:57	**2 NOV** 32.1% 14:48 --:--	**3 NOV** 21.6% 01:16 15:14	**4 NOV** 12.9% 02:34 15:38
5 NOV 6.2% 03:51 16:01	**6 NOV** 1.9% 05:07 16:24	**7 NOV** NM 0.2% 06:23 16:49	**8 NOV** 1.0% 07:36 17:17			

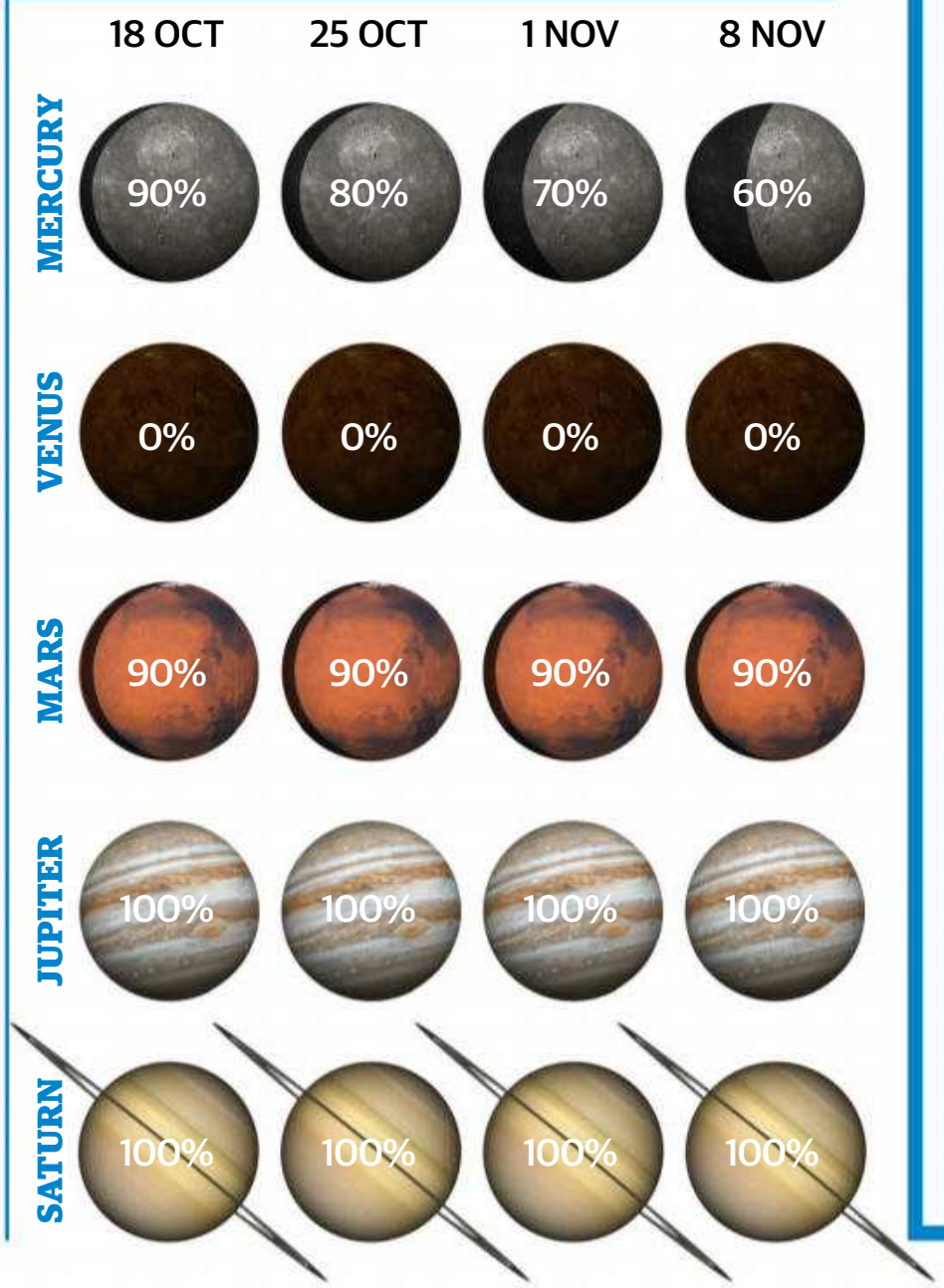
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

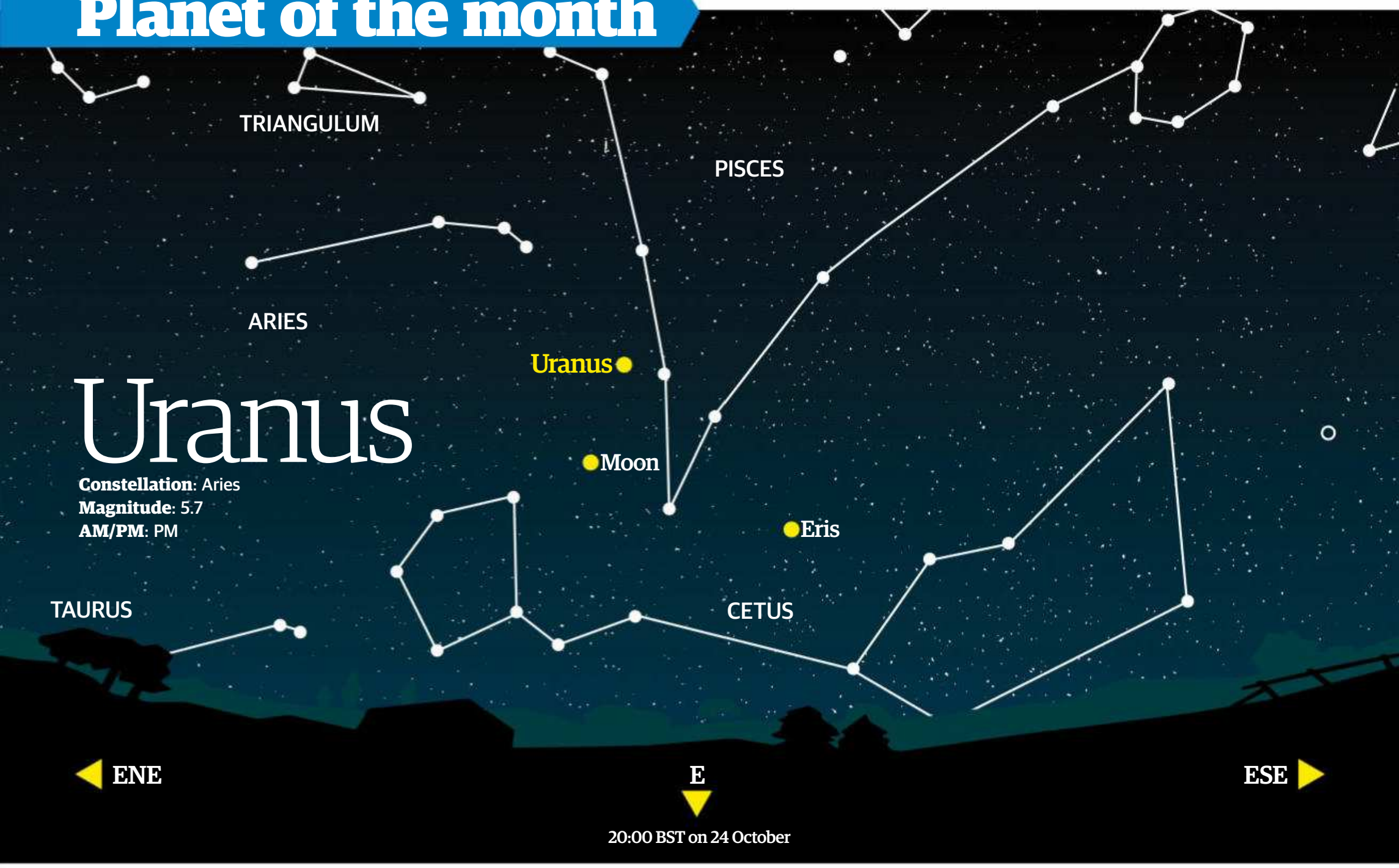
All rise and set times are given in BST/GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	11 Oct	13h 55m 37s	-12° 27' 30"	Virgo	-0.4	08:43	18:46
	18 Oct	14h 35m 32s	-16° 40' 36"	Libra	-0.3	09:19	18:35
	25 Oct	15h 14m 38s	-20° 11' 24"	Libra	-0.2	09:51	18:26
	01 Nov	15h 52m 01s	-22° 50' 56"	Scorpius	-0.2	09:17	17:19
	08 Nov	16h 24m 35s	-24° 27' 02"	Ophiuchus	-0.3	09:33	17:13
VENUS	11 Oct	14h 20m 29s	-21° 51' 50"	Virgo	-4.4	10:02	18:17
	18 Oct	14h 11m 06s	-20° 57' 14"	Virgo	-4.3	09:20	17:46
	25 Oct	13h 56m 59s	-18° 55' 02"	Virgo	-4.0	08:26	17:17
	01 Nov	13h 42m 44s	-16° 08' 48"	Virgo	-4.1	06:28	15:51
	08 Nov	13h 33m 00s	-13° 22' 44"	Virgo	-4.4	05:36	15:29
MARS	11 Oct	20h 53m 30s	-20° 57' 00"	Capricornus	-1.1	16:28	00:59
	18 Oct	21h 06m 57s	-19° 38' 38"	Capricornus	-0.9	16:06	00:52
	25 Oct	21h 21m 16s	-18° 13' 35"	Capricornus	-0.8	15:45	00:48
	01 Nov	21h 36m 15s	-16° 42' 13"	Capricornus	-0.6	14:23	23:40
	08 Nov	21h 51m 45s	-15° 04' 58"	Capricornus	-0.5	14:02	23:37
JUPITER	11 Oct	15h 26m 14s	-17° 59' 36"	Libra	-1.8	10:44	19:46
	18 Oct	15h 31m 59s	-18° 21' 08"	Libra	-1.8	10:25	19:22
	25 Oct	15h 37m 57s	-18° 42' 31"	Libra	-1.7	10:05	18:58
	01 Nov	15h 44m 05s	-19° 03' 34"	Libra	-1.7	08:46	17:35
	08 Nov	15h 50m 22s	-19° 24' 08"	Libra	-1.7	08:26	17:12
SATURN	11 Oct	18h 14m 04s	-22° 46' 30"	Sagittarius	0.5	14:01	22:04
	18 Oct	18h 15m 52s	-22° 46' 46"	Sagittarius	0.5	13:35	21:38
	25 Oct	18h 17m 58s	-22° 46' 48"	Sagittarius	0.5	13:10	21:13
	01 Nov	18h 20m 19s	-22° 46' 33"	Sagittarius	0.6	11:45	19:48
	08 Nov	18h 22m 54s	-22° 46' 01"	Sagittarius	0.6	11:20	19:23

This month's planets

The turquoise ice giant dominates the evening sky this October, while other members of the Solar System make an evening appearance

Planet of the month



Uranus

Constellation: Aries
Magnitude: 5.7
AM/PM: PM

Rather bizarrely, it could be said that Uranus is 'dominating' the evening sky this month. How could that possibly be? After all, the planet's low magnitude of 5.7 means that technically it is a naked-eye object, but in reality it is only visible with the assistance of a pair of binoculars or a telescope to observers with almost-perfect eyesight looking for it from a dark-sky location without any interference from the light pollution caused by artificial lights, or from the bright glow of the Moon.

Even under those perfect conditions the planet's low magnitude means that it does not stand out from the other stars around it; to identify which of the many dots in the sky Uranus is, an observer needs to know the planet's position relative to all those background stars very, very accurately. That will require the use of a detailed star chart, either generated by an app on a phone or tablet, an astronomy website or a computer planetarium program such as Stellarium.

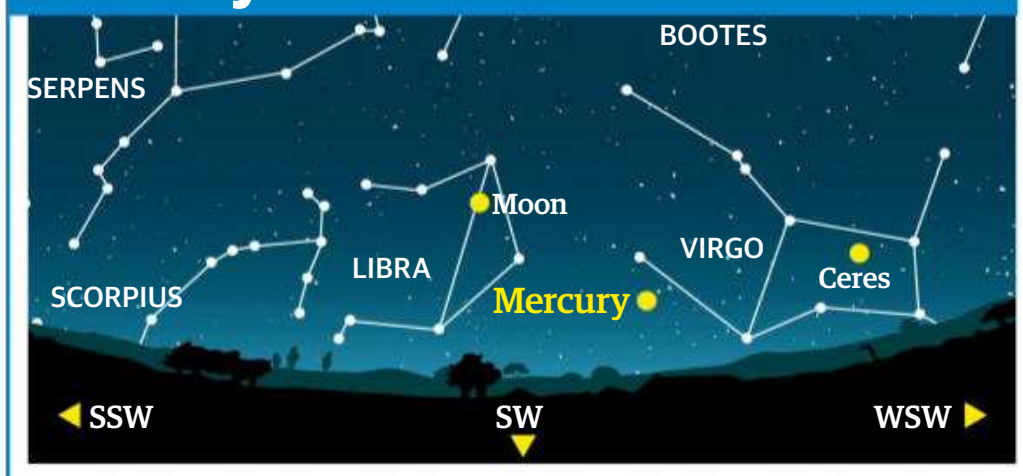
Then, when you've pinned down which part of the sky it is in, if you want to see Uranus itself you will need to scan the sky using a pair of binoculars or a small telescope to make the planet stand out more clearly. Through a pair of binoculars Uranus is given away by its colour alone – it appears as a green-white 'star' surrounded by less colourful, but brilliant, white or blue-white stars.

Through a small telescope Uranus will stand out from the celestial crowd more obviously because it will look like a tiny, pale-green disc instead of a sharp point of light. Higher magnifications make the disc larger, but will also enhance its subtle colour. If you're the owner of a 12" or larger telescope Uranus will look a lot like a planetary nebula, minus the central star of course.

If Uranus is so unimpressive, why bother looking for it in the first place? Because – as with so many things in the night sky – the appeal of looking at Uranus isn't its actual appearance in your eyepiece, but knowing and appreciating what it is you're looking at. The good news is that this month you'll have plenty of time to track it down on the next clear night because it is visible right through the night, from dusk until dawn. As the sky darkens after sunset you'll find Uranus over in the east, already quite high, shining just inside the southern border of Aries. It will then be carried from east to west through the evening, and by the time the western sky is starting to brighten with the approach of dawn it will be low in the west.

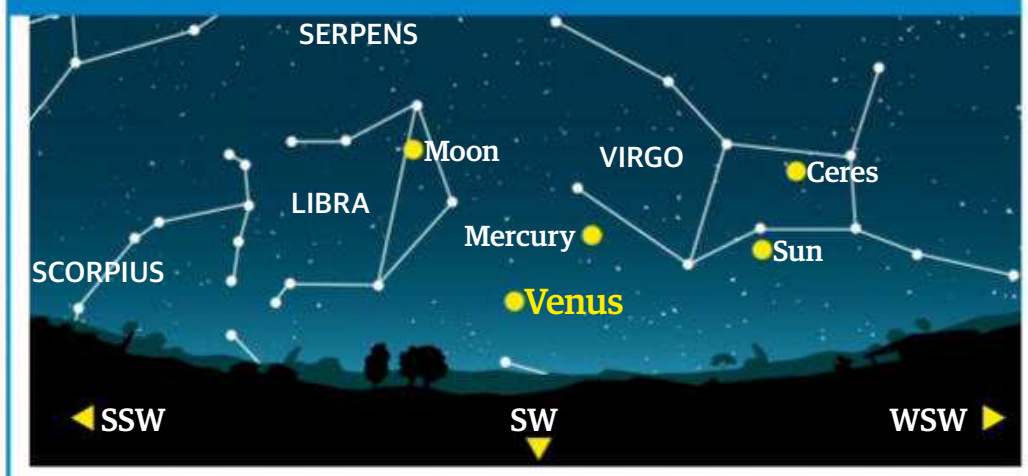
This month's planets

Mercury 18:00 BST on 11 October



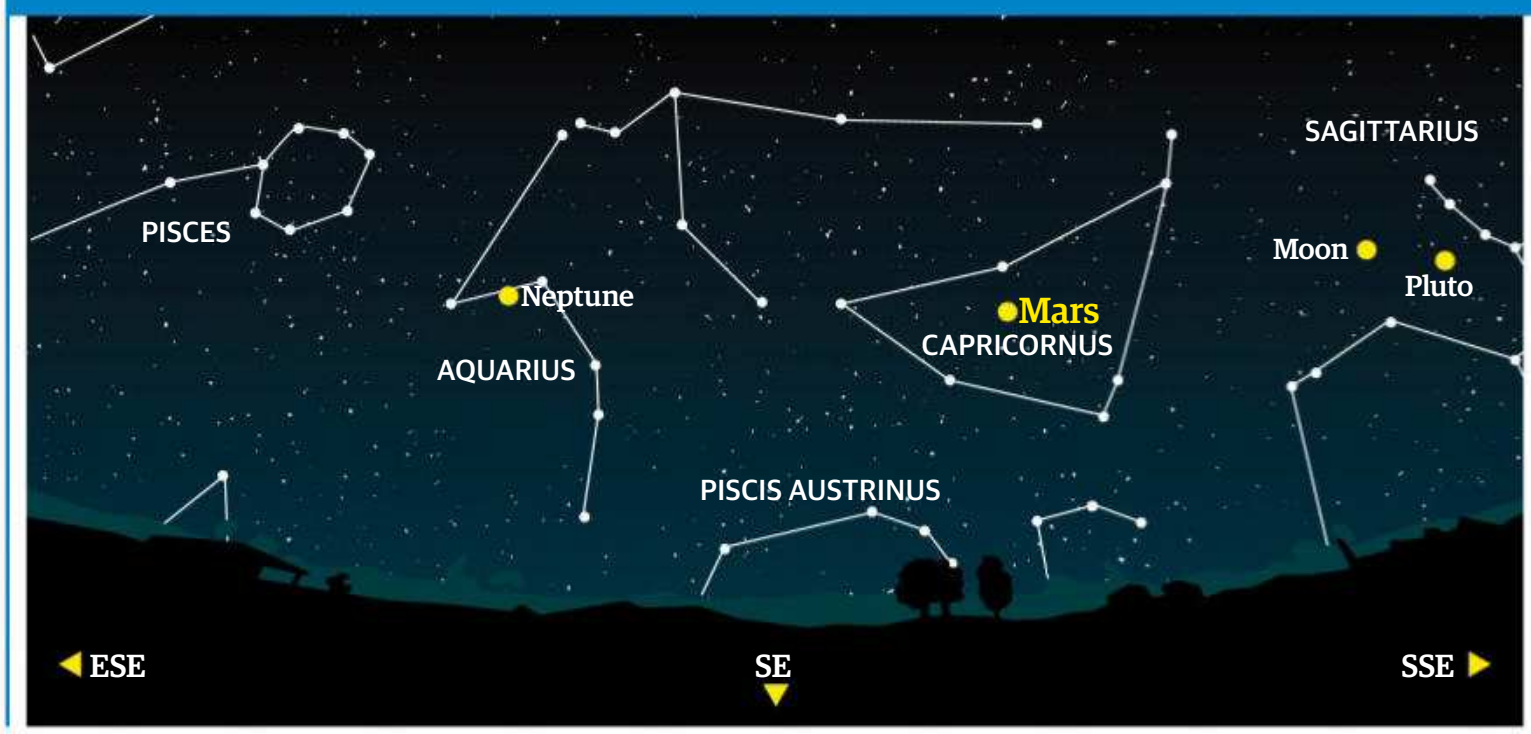
Constellation: Virgo
Magnitude: -0.4
AM/PM: PM
Another very frustrating month for any planetary observers who want to see the closest planet to the Sun. At the start of our observing period Mercury is setting just a handful of minutes after the Sun, so will be impossible to see. Prospects improve as the days pass and Mercury edges away from the Sun.

Venus 17:00 BST on 11 October



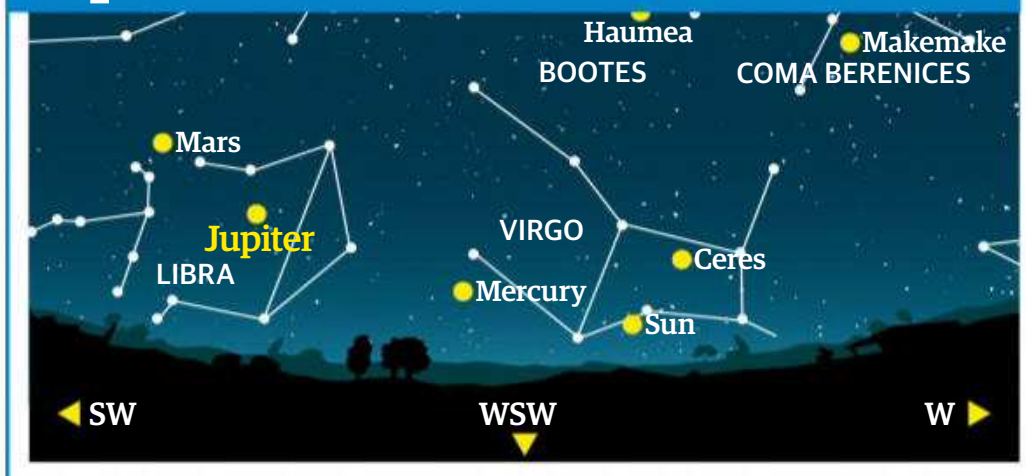
Constellation: Virgo
Magnitude: -4
AM/PM: AM & PM
At the start of our observing period Venus will technically be an evening object, but in reality it will be too close to the Sun to be visible. As October passes Venus will edge closer and closer to the Sun. By the end of our observing period Venus will have emerged from the Sun's glare and will be visible before dawn.

Mars 19:00 BST on 16 October



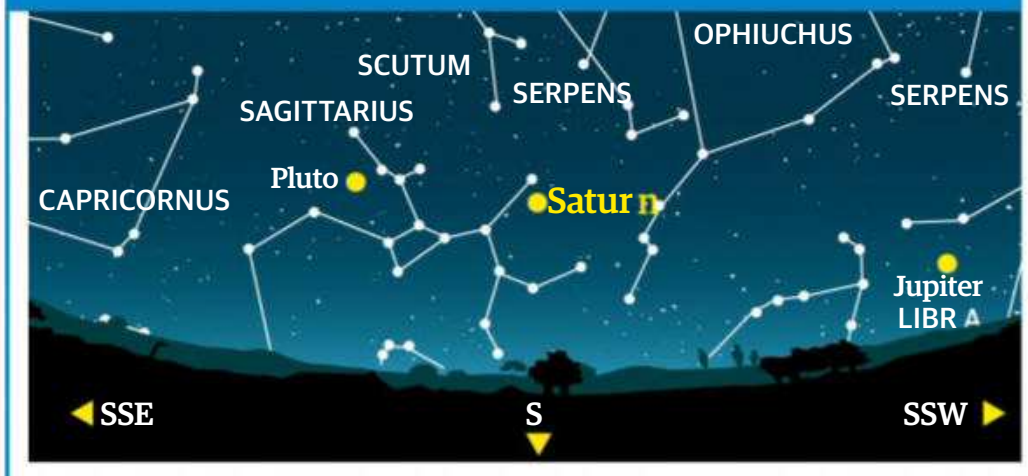
Constellation: Capricornus
Magnitude: -1.3 fading to -0.4
AM/PM: PM
As October begins Mars' beautiful and bright opposition will be just a distant memory. By now the planet will be much fainter than it was in summer – still an easy naked-eye object, but nowhere near as impressive. The Red Planet will be visible from sunset to just after midnight, looking like a star in the middle of the roughly triangular constellation. It will move slowly across the southern sky through the evening, setting just after midnight. The waxing Moon will approach and pass it between 16 and 18 October, the two objects making an interesting close pairing after dark on the evening of 17 October.

Jupiter 18:00 BST on 12 October



Constellation: Libra
Magnitude: -1.8
AM/PM: PM
Mighty Jupiter lies low in the south west after sunset; you might even need a pair of binoculars to pull it out of the bright dusk sky. As October slides into November Jupiter will become harder to see, edging steadily closer to the Sun, and you really will need a flat, low south-western horizon to have a chance of seeing it.

Saturn 18:00 BST on 21 October



Constellation: Sagittarius
Magnitude: 0.5
AM/PM: PM
During our observing period the huge, ringed planet can be seen looking like a yellow-hued, naked-eye star just above and to the right of the well-known 'Teapot' asterism in the constellation of Sagittarius after sunset. By the middle of November Saturn will be low in the sky after sunset and harder to see.

Top tip!

Try to observe Eddington when the Moon's libration tips it towards us - it will be a lot easier to see than when it is on the lunar limb.

Moon tour

Eddington

See the lava-flooded remains of a once-proud crater

Understandably, the most famous and popular lunar features are those which are presented almost face-on to us. The ray-sploshed craters Copernicus and Kepler; the curved, bony spine of the Appennine Mountains and the great vertical crater chain of Ptolemaeus, Alphonsus and Arzachel are all very central on the Earth-facing side of the Moon and so are observed, photographed and sketched much more often than other craters and mountains closer to the limb of our planet's natural satellite.

However, if you can drag your eyes – and swing your telescope – away from the centre of the Moon you will be rewarded with some fascinating and intriguing sights as you gaze across features foreshortened by their proximity to the Moon's curved edge.

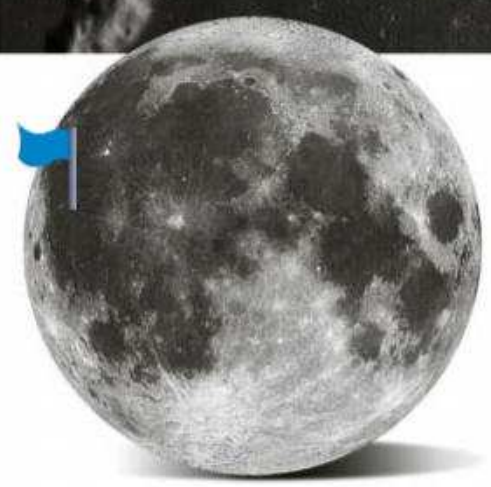
One such feature is the crater Eddington – or, rather, what is left of the crater Eddington. Many millennia ago Eddington (named after famous astrophysicist Arthur Eddington, who was born in the Lake District town of Kendal, less than a mile from where I'm writing these very words!) was a crater like countless tens or even hundreds of thousands of craters on the Moon – the ancient scar left behind when an asteroid slammed into the Moon and blasted a hole out of its rocky crust. It probably remained like that for a long time, but then something very dramatic happened that changed Eddington forever...

A huge piece of space debris slammed into the Moon somewhere close to Eddington, melting a vast area of the surface into molten lava. This lava flowed across the surface of the Moon towards Eddington – then rolled up and over its southern walls and overwhelmed them, flooding the interior of the crater and smothering any features on its floor and on the lower reaches of its walls.

When this glowing, bubbling tsunami of melted rock eventually settled and cooled, the southern part of Eddington was gone, hidden beneath kilometres of cooling, darkening rock. If it had once had a central peak standing on its floor, that was lost from sight too. All that remained of the crater was the semi-circular arc of its northern rim and a few smaller, lower 'islands' of rock to the south – the highest parts of its southern walls. Eddington was now a 'crater remnant', the ghost of a once proud feature.

If Eddington had been blasted out of a region of the Moon more central on the Earth-facing side, even after its heart had been flooded with lava it would have been easily visible from our planet through a pair of binoculars as a bright, roughly semi-circular feature with a dark floor and smaller satellite craters dotted around it.

However, as it was created near the north-western limb of the Moon it appears very foreshortened to us, little more than an oval, and a telescope is needed to see it. Even then all you will see is the arc of its northern edge, which makes the crater remnant look more like the front end of a pair of tweezers than a semi-circle. If you view Eddington at high magnification you will be able to see a few tiny craterlets dotted across its dark, almost-flat floor to the north west, and to the south east you'll see two tiny arcs. This is Eddington P – a smaller, lava-filled ghost crater on the floor of the ghost crater of Eddington itself.



At the start of our observing period Eddington cannot be seen; you'll have to wait until 23 October for your first glimpse of it as the terminator – the line between lunar night and day – sweeps over it and its eastern side is kissed by the Sun's rays again. For the following three or four days Eddington will be as well placed for observation as it ever gets: the Moon's libration – its slow wobble around its axis – will tip the crater towards us during that time, before pulling it away from us again. Eddington will vanish from our view on 4 November when the terminator slides over it again, plunging it back into darkness, and it will not be visible again during this month's observing period.

© NASA

This month's naked eye targets

A blue supergiant, a dark rift and the famous 'Double Double' are on display

Cygnus Star Cloud (Cygnus X)
Running down the right-hand side of Cygnus, the Cygnus Star Cloud is a mass of faint stars very obvious to the naked eye under a dark sky. When we look towards it we are looking down the length of our own spiral arm within the Milky Way, where it begins to curve in towards the galaxy's centre. Binoculars will show countless thousands of faint stars within it.

Lacerta

Deneb (Alpha Cygni)
The brightest star in Cygnus (the Swan), blue-white Deneb is the 19th-brightest star in the sky. Around 2,600 light years away, it is an enormous supergiant star which would swallow up Mars' orbit if put in our Sun's place. It is more than 200,000-times more luminous than the Sun.

Cygnus

The Great Rift
Look at Cygnus under a dark sky and you will see a dark lane running down its left, almost as if someone had dusted away the stars from that part of the sky. It is actually a number of overlapping dark dust clouds lying between us and the Milky Way's Sagittarius Arm, obscuring its stars from view.

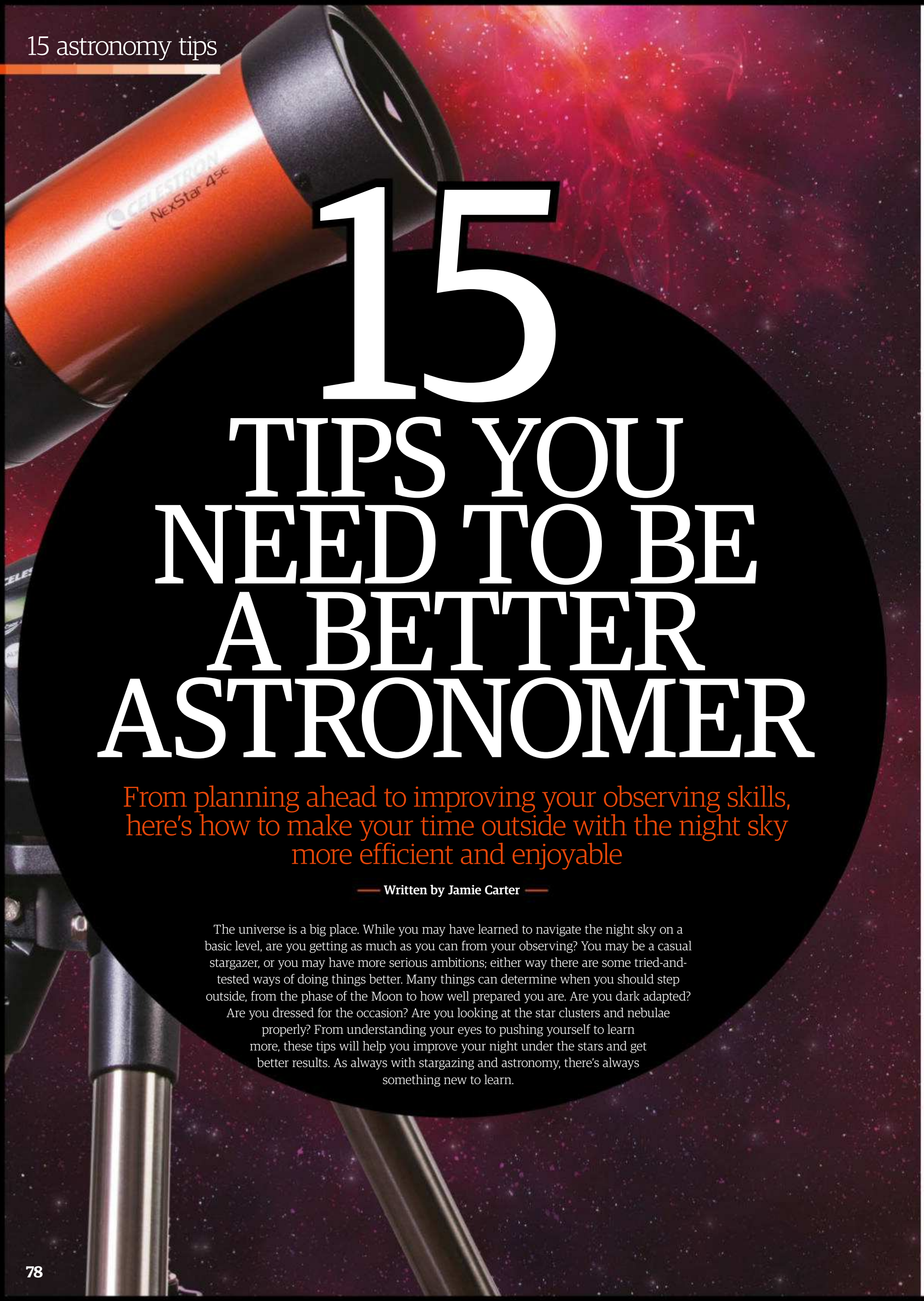
Lyra

Sagitta

The Coat Hanger (Brocchi's Cluster)
This star cluster comprises of around 40 faint stars, the brightest ten of which are arranged roughly in the shape of a coat hanger. It can be seen with the naked eye in a dark sky, but binoculars will highlight the differences in colour between the cluster's brightest stars.

The Double Double (Epsilon Lyrae)
Lying just over one-and-a-half degrees north of brilliant-blue Vega, Epsilon Lyrae is one of the most famous double stars in the sky. A pair of binoculars shows it as two stars of equal brightness, very close together, and a telescope shows each of those stars is a double too – hence its nickname, 'The Double Double'.

© Will Tirion



15 TIPS YOU NEED TO BE A BETTER ASTRONOMER

From planning ahead to improving your observing skills, here's how to make your time outside with the night sky more efficient and enjoyable

Written by Jamie Carter

The universe is a big place. While you may have learned to navigate the night sky on a basic level, are you getting as much as you can from your observing? You may be a casual stargazer, or you may have more serious ambitions; either way there are some tried-and-tested ways of doing things better. Many things can determine when you should step outside, from the phase of the Moon to how well prepared you are. Are you dark adapted? Are you dressed for the occasion? Are you looking at the star clusters and nebulae properly? From understanding your eyes to pushing yourself to learn more, these tips will help you improve your night under the stars and get better results. As always with stargazing and astronomy, there's always something new to learn.

Check with the Moon



1 Are you stargazing at the right time of the month? During full Moon our satellite rises at dusk and sets at dawn, effectively acting as a giant light polluter all night long. That makes the night of the full Moon the worst night of the month for stargazing and astronomy. The four or so days either side of full Moon also see a bright Moon dominating the night sky, blotting out stars and constellations. So when should you go stargazing? The darkest night of all is that of new Moon, exactly two weeks after and before full Moon. During that time the Moon is between the Earth and the Sun, so from Earth we can see none of the illuminated side of the Moon. However, for around four or so days before new Moon, a waning Moon rises after midnight, and just after new Moon, it's a slim waxing crescent that sets soon after dusk. So if you really want to plan the perfect night of stargazing, aim for new Moon week.



Have an observing list

2 Stepping outside into the dark instantly knowing what stars and constellations are above you at that time of night, and that time of year, is one of the joys of long-term stargazing. However, you need to keep learning new things to keep things interesting. The easiest way is to get hold of a book of observing targets. Another way is to choose a constellation to explore in detail using binoculars or a telescope, or develop a interest in galaxies, nebula or star clusters and hunt for those.

Choose a dark-sky site

3 Unless you live 30 or so miles from the nearest town or city, your stargazing will be affected by light pollution. That's not quite the disaster it may seem when you're starting out, because light pollution only allows the brightest stars to be visible. This can make it easier to get to know the night sky, allowing you to find constellations easily. However, if you go to a place with very little light pollution, you'll be amazed by what else you can see.



Plan ahead

4 Are you missing a big night-sky event such as a meteor shower, a planetary conjunction or even a lunar eclipse? Find an astronomy calendar online and you can discover the key dates for major events in the night sky. If you know the dates of forthcoming meteor showers, plan to stargaze during them and you'll hopefully catch a shooting star or two. Also keep an eye on the movements of the planets, especially their date of 'opposition'; when a planet comes into opposition, Earth is precisely between the Sun and that planet, so it shines more brightly. The same goes for planetary conjunctions. When two planets appear to be close to each other in the night sky, find out the date and make a plan to stargaze.

However, you should plan ahead more generally. For example, if you want to point a telescope at a faint fuzzy object, such as a galaxy or nebula, find out when it will be at the zenith (directly above your head). That's the darkest part of the sky, so the best place to observe it.



Get up high

5 Elevation is everything. There are two reasons why getting yourself into an observing position high up is important. The first is that you can look to the horizons. Such a technique will help you find the planet Mercury, which is mostly hidden in the Sun's glare. The second reason for elevation is the clarity of the night sky. If you stargaze from a high altitude area you're above the densest portion of Earth's atmosphere, which causes atmospheric refraction, and so distortion. From a mountainous area stars don't twinkle, they glow, which is why the major astronomical observatories are in high-altitude areas such as Chile, Hawaii, and the Canary Islands.

© ESO

Dress properly and eat well

6 Hikers and outdoor adventurers spend incredible amounts of money on clothing and equipment to keep themselves warm. However, they're moving around a lot so producing their own heat. In contrast, stargazing doesn't involve much moving. This can mean you can get very cold, especially in winter when even the thought of going outside to look at the stars can send shivers down your spine. A hat and scarf/neck warmer are other essentials, and make sure to take a hot drink and snacks.



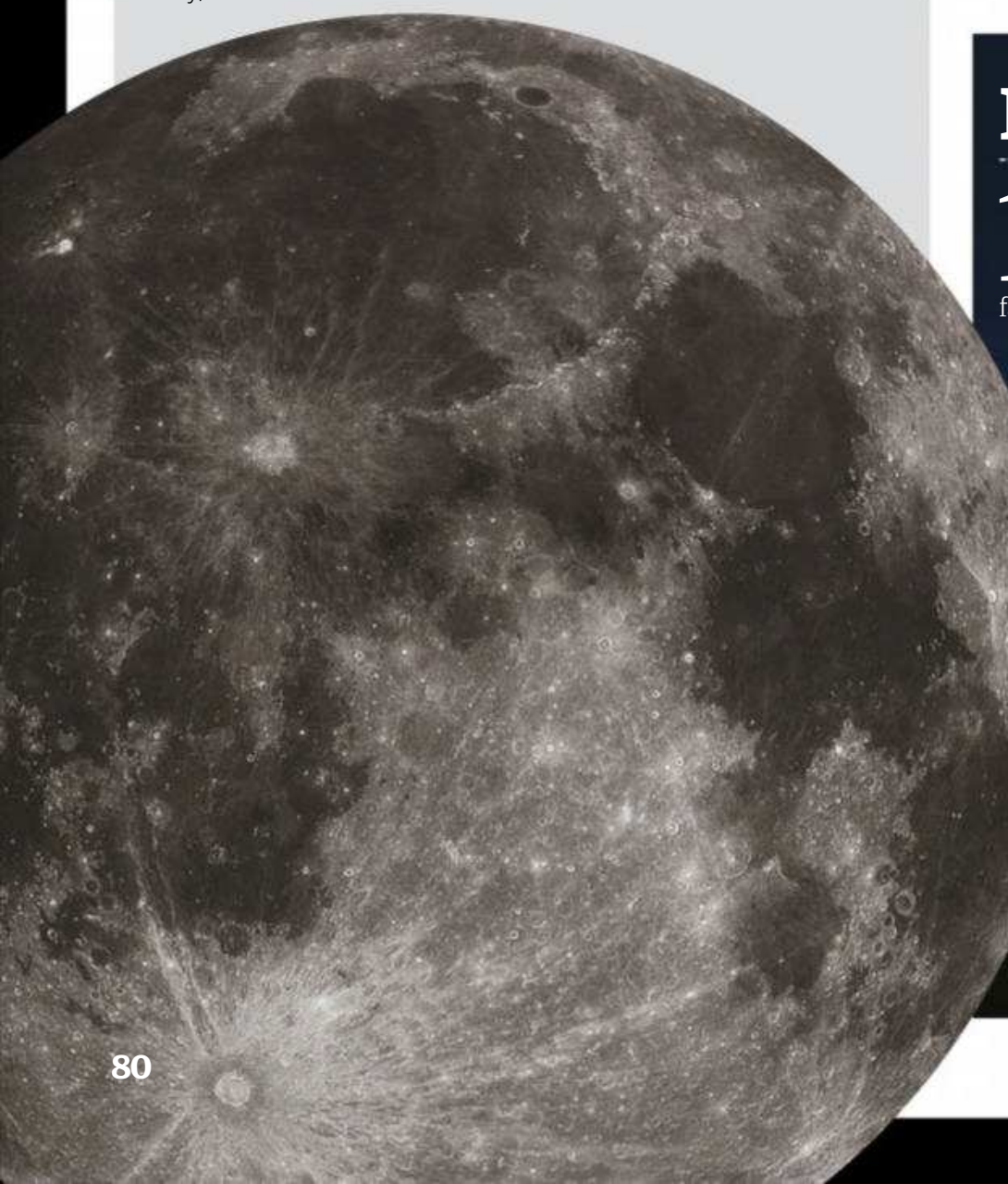


Dark adapt your eyes

7 Stand somewhere completely dark for a period of time and your pupils will dilate to let in as much light as possible. That way you'll see far more stars, and you'll have a chance of seeing the Milky Way. For stargazing and astronomy dark-adapting your eyes is essential, and will happen after about 20 minutes. Remember to take a red-light torch outside with you. Any other kind of light will instantly kill your night vision.

Get to know the Moon

8 Can you pick out the major features on the Moon? Many a stargazer has been distracted by the Moon, and it may even be why you got hooked on the night sky to begin with. Either way, it's worth getting to know its geography. The best time to Moon-watch is the first week after new Moon, between its waxing crescent and first quarter phases. Night after night you can watch the Moon's surface slowly being revealed to you, from major craters Tycho, Copernicus and Aristarchus to the dark-grey lava plains such as the Sea of Serenity, the Sea of Tranquility and the Sea of Fertility. It may also be of interest to be able to identify where man walked on the Moon during the Apollo missions of the 1960s and 1970s. With binoculars you can easily see the general location of Moltke Crater and the nearby 'Tranquility Base' in the Sea of Tranquility where Apollo 11 astronauts Neil Armstrong and Buzz Aldrin walked on 20 July, 1969.



Rehearse and relocate

9 How can you possibly remember the names of the 5,000 or so visible stars in the night sky? The truth is you can't, but you can learn to navigate the night sky quite easily. It's all about getting into good habits. When you step outside into the darkness at your usual stargazing location – most likely your back garden – take a few minutes to identify major constellations and bright stars that are easily visible to you. At the beginning of your learning you might pick out the Big Dipper one week, the Big Dipper and Cassiopeia the next week and in the third week use both of those constellations to find Polaris, the North Star. Even when you're semi-experienced in stargazing rehearsing what you already know is useful, particularly when done in a new location or somewhere you do not usually observe from.



Find planets quickly

10 Finding 'wandering stars' should be difficult, and most people think that planets can be seen at any time and in any position in the night sky. After all, planets are always moving as they orbit the Sun at different speeds. In fact, it's easy to find planets because there's a line going from east to west across the night sky on which all planets are found. This is the ecliptic, and it's the path the Sun takes across the daytime sky. Note where sunrise and sunset take place, and have a rough idea of where the Sun is at noon, and you've got it. The ecliptic is nothing short of the flat plane of the Solar System, which stargazers get to see side-on, and it's here – and only here – that you'll see planets during darkness. So don't ever look to the north, or directly above, and speculate whether a bright star could be a planet. It's way simpler than that.



© NASA/ESA; ESO; Gregory H. Revera; Shenandoah National Park; Tatters; Quarkgluonplasma;

Understand your eyes

11 Observing the night sky can be done anywhere, any time and by anyone, whatever their level of knowledge. However, that doesn't mean there aren't ways to make your own observing more effective. Perhaps the most important technique is that of averted vision. It's based on the fact that the human eye's peripheral vision is the most sensitive to brightness, whereas it's centre is more sensitive to colour. If you're observing star clusters, galaxies and nebulae - objects with incredible collective brightness - with the naked eye or through binoculars, look slightly to the left or right of the object. That way your eyes will better detect its brightness. This works well for objects like the Pleiades star cluster, the Orion Nebula and the Andromeda Galaxy. The same technique works in a slightly different way if you're observing through a telescope; if your left eye is to the eyepiece, look slightly to the left of the object, and vice versa. You can also try looking slightly above and below, too.



Find the ISS

12 Stargazing doesn't just have to be about looking deep into the galaxy and the universe beyond; it can also be about observing man-made objects orbiting our planet. Easily the most impressive is the International Space Station (ISS), which orbits Earth 16 times each day and travels faster than a speeding bullet around 402 kilometres (250 miles) up. If you want to see the ISS from where you are, consult NASA's **spotthestation.nasa.gov** website to get exact timings. Transits take around four minutes, always generally from west to east, and always in the few hours after sunset or before sunrise, when the Sun catches the ISS' solar panels, which is what you actually see. Since the ISS only takes 90 minutes to orbit the planet, if you do see it just after dark there's a good chance you'll see it again 90 minutes later further to the north in the night sky. Either way, the ISS is so bright and so impressive an observing target that it will quickly become a staple of your stargazing.

Use your mind's eye

13 There's a lot more to the night sky then you can see. With the naked eye you're only penetrating that first layer of the night sky: visible stars, clusters and the occasional galaxy. Even with binoculars or a powerful telescope there's only so much you can see. However, the news is littered with new astronomical discoveries. Can you find them in the night sky? For example, most exoplanets found by astronomers using the Kepler space telescope are in two tiny patches of sky around the constellations of Lyra and Cygnus. Here's another; the first exoplanet ever discovered, in 1995, was 51 Pegasi b in the constellation of Pegasus. It's about halfway between the bright stars Scheat and Markab, and it's where the term 'hot Jupiter' comes from. Halley's Comet? It resides in front of the constellation of Hydra, close to bright star Sirius.

Try to marry together what you observe with what you hear about in the news, and not only will you get a deeper understanding of the night sky, but you'll be able to navigate it on a whole new level using nothing more than your mind's eye.





Identify a new constellation

14 So you've learned a few constellations. You've probably been focusing on constellations fairly high up in the sky, where stars appear brighter and are easier to identify. So what about the constellations low on the horizon? These can be much more difficult to identify. Any constellation that is rising in the east can be forgotten about for a few hours and viewed later on that night when it's higher and easier to see. It's worth getting to know the 13 zodiacal constellations which lie across the celestial equator precisely. It's both challenging, and will take most of the year. While Taurus, Gemini, Cancer and Leo are all easy to find, the others (Aries, Virgo, Libra, Scorpius, Sagittarius, Capricorn, Aquarius, Pisces and the 'forgotten' one, Ophiuchus) can be rather tricky to identify. Not only are they relatively low on the southern horizon, but some of their constituent stars are rather hard to find. However, do persevere, because the fainter and more complex the constellation, the more joy you will get from finding it in the night sky.

Get some good binoculars

15 Before you jump ahead and buy a telescope, remember that the sky comes in three layers. The first is everything you can see with the naked eye. The third is what you can see with the telescope. Don't forget the second layer, which you can only really appreciate with a good pair of binoculars. Not only are they portable, they give you a stereo view of the heavens and a much wider field of view than a telescope can, and binoculars are the only way to look at some objects in the night sky.





How to...
Photograph star trails

Taking beautiful photos of the stars trailing across the sky is easy. All you need is the right camera, a tripod, and a clear sky...

You'll need:

- ✔ A dark-sky site
- ✔ A DSLR camera
- ✔ A 50mm lens
- ✔ A tripod
- ✔ A cable release
- ✔ Photo-processing software

Today, motorised 'star trackers' are quite cheap and readily available. After being aligned on the Pole Star, they follow the stars as they circle around it, allowing astro-photographers to take long-exposure photos of the constellations, the Milky Way, galaxies and nebulae without them trailing. But sometimes you want that trailing; star trail photos can be just as attractive, especially if they include foreground objects such as trees, hills and even buildings. Star trail photos also show the colours of the stars more vividly than tracked shots. All you need to take a good star trail image is a DSLR camera on a tripod – it's that simple.

Usually in astrophotography, finding a dark-sky site is crucial, but you can take star trail photos from just about anywhere, even from a light-polluted back garden. Of course, the darker your sky the more stars your photos will show, but a dark sky isn't as essential as it is for photographing the Milky Way, a meteor shower or the northern lights.

You don't need a specialised lens either. Your DSLR probably came with a 'standard kit' lens, something like an 18–55mm lens. You can set it to 50mm or just use a 50mm lens on its own. Other lenses will work, so use whatever you have, but 50mm is a good lens to start with. Don't use a long, zoom-type lens; it will have such a small field of view you'll only capture a few trails.

To record stars as trails rather than pinpricks of light you have to take long exposures. The longer the exposure, the longer the star trails will be, as the stars will have moved a greater distance across the sky during that time. But take too long an exposure and you risk overexposure.

If you can include some foreground objects in your photos, so much the better. Star trails shining through the branches of trees, arcing above hills or reflected in the still water of a lake can look breathtaking.

"All you need to take a good star trail image is a DSLR camera on a tripod – it's that simple"

Tips & tricks

Find a dark sky

Although you can take star trail photos from your back garden, you'll capture more stars if you can find somewhere dark with no light pollution.

Keep it tight

Make sure your camera is fixed firmly on your tripod and that all the knobs and controls are tightened and in place before taking photos. The slightest slip will give you blurry pictures.

For once, 'standard' is absolutely perfect

You don't need an expensive wide-angle lens to take lovely star trails, and zoom lenses are no use at all. The standard (typically 18–55mm) lens that came with your camera is perfect.

Every second counts

Experiment until you find the right exposure length – long enough to record the stars but not so long that they are washed out by light pollution.

Getting that perfect shot

It's all about a bit of mix and match

After some experimentation you'll have found the right exposure times and ISO settings to use with your equipment to record good star trails. What you can do then is take lots of images of the same view. You can then import these into special free software, which will combine them all into a single image, effectively creating a single super-long exposure the sum of all the individual exposures.

Send your photos to
space@spaceanswers.com



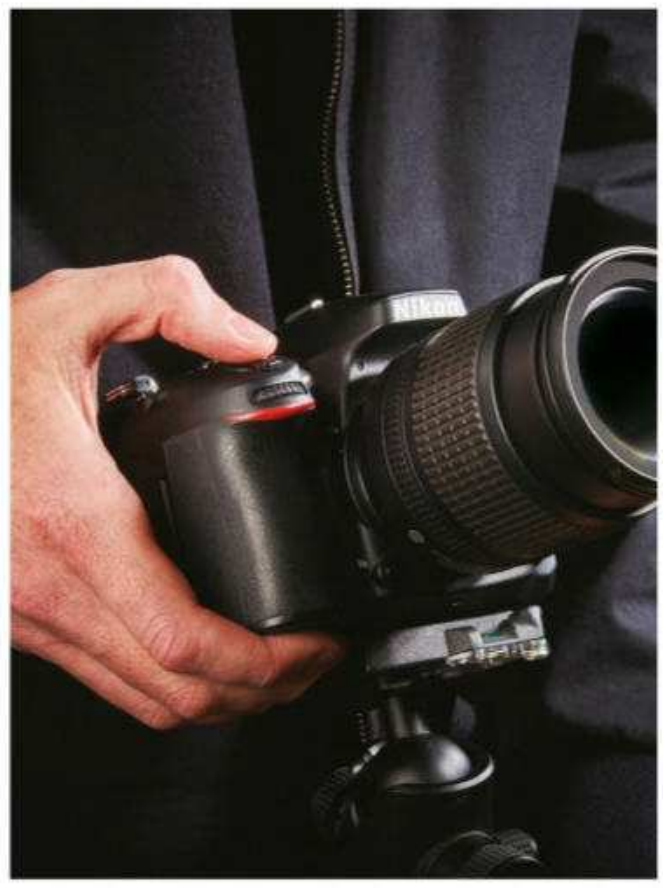
1 Get a sturdy set up

Fix your camera to a sturdy tripod to keep it as steady as possible. Be sure to carefully check that nothing on your tripod will move or slip during your long exposures.



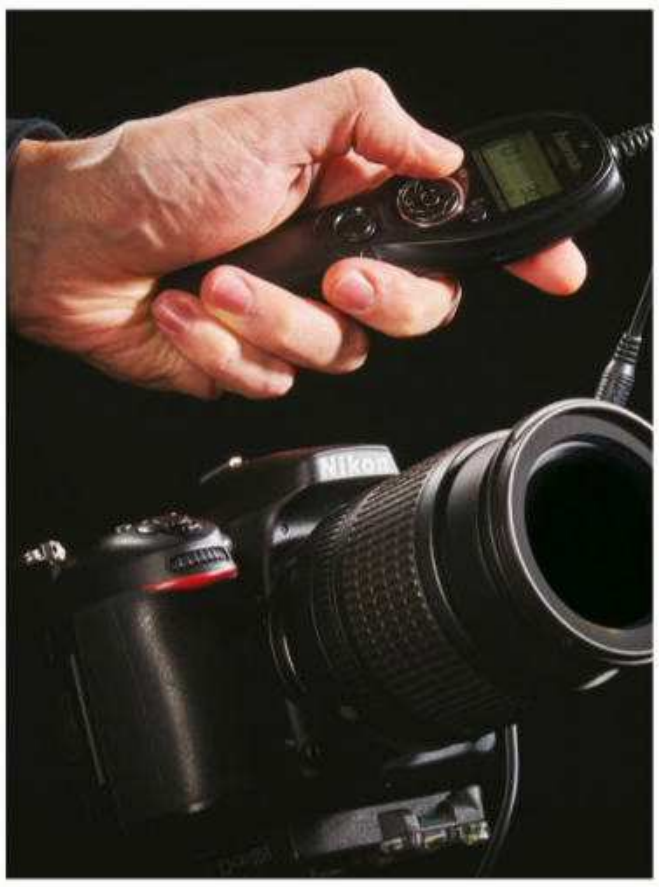
2 Tweak your settings

Set your lens to 50mm and open it to its widest aperture (ideally under f3). Set your camera to Manual mode, the ISO to 400 and the exposure time to 30 seconds. Set a time delay too.



3 Choose a familiar target

Now direct your camera at a constellation that you know and then focus it sharply on either a bright star or a distant light on the horizon. It's almost time to get snapping!



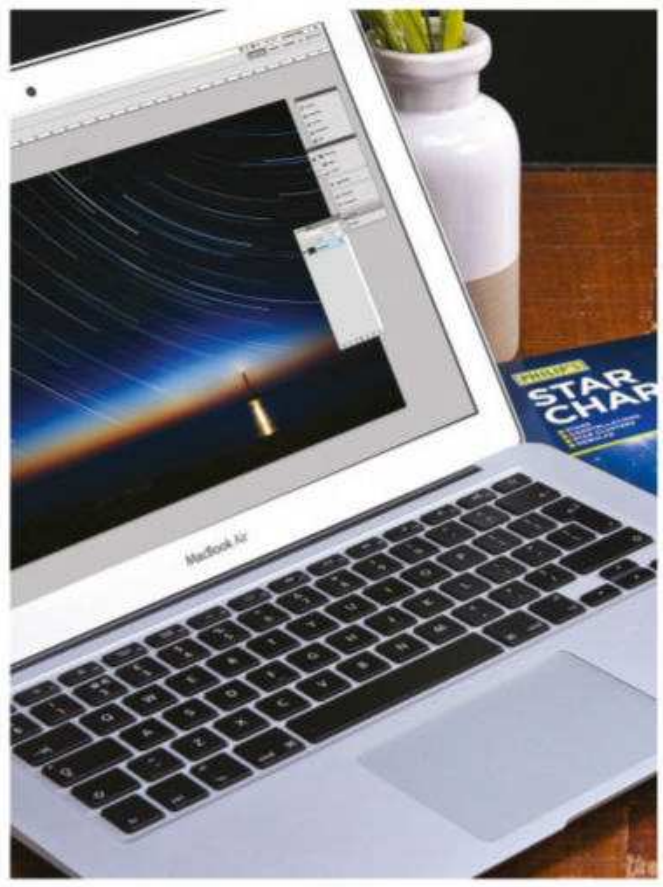
4 Take your first shot

When you are ready, press the cable release to take your first image. You will see that the stars will have trailed. If you find it is too dark increase the ISO.



5 Get creative!

To be more artistic, point your camera in a direction in which there are stars or a bright planet shining above features in your local landscape. Take lots of images of this view.



6 Combine your shots

You can use free software to combine your series of star trail images to make one very striking single image showing very long star trails with the foreground in focus and not blurred.

© Antoine Lamielle

Silver Sliver Galaxy (NGC 891)

Deep sky challenge

Autumn's fading galaxies

Winter is coming, but some of autumn's deep-sky treasures can still be enjoyed through your telescope

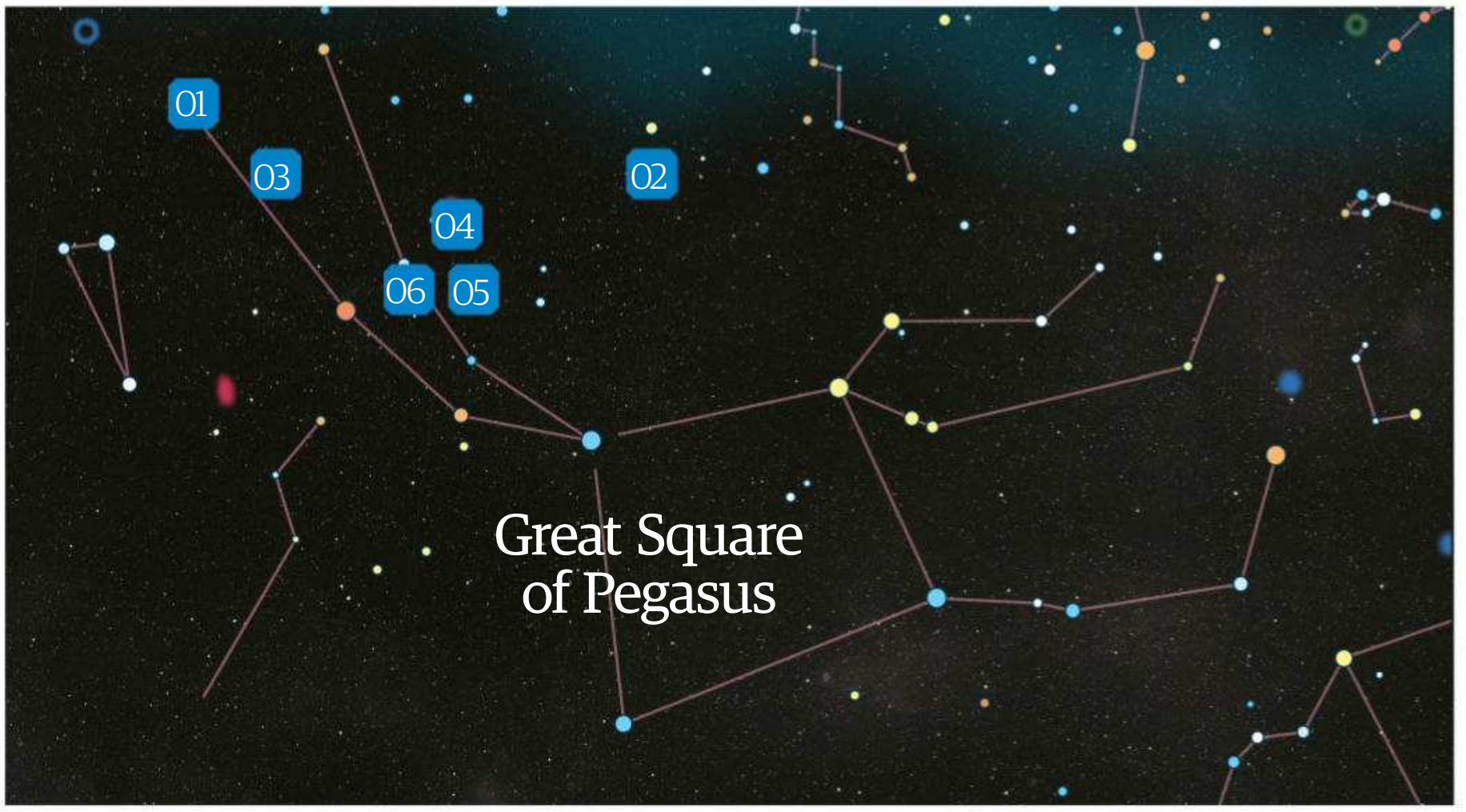
As October slides into November it's only natural to swing your telescope away from the subtle attractions of the autumn sky and use it to enjoy views of winter's bigger, brighter and bolder deep-sky objects. But before you start diving headfirst into the swirling grey and green gas clouds of the Orion Nebula or squint at the Crab Nebula's ghostly outline, why not postpone winter a little longer and give some of autumn's delights one last look?

If you view from a dark sky, your small telescope will show you the two small, faint satellite galaxies of M31, the famous Andromeda Galaxy. Owners of larger instruments which can provide higher magnification and gulp down more subtle starlight can see a nebula that, supposedly, resembles a blue snowball, and a fine edge-on galaxy too.

There's also a faint comet to track down this month – Comet 64P/Swift-Gehrels is waiting for you to find it, conveniently positioned halfway between Mirach and M31. It's small and very faint, so you'll need patience – and a big mirror or lens – to see it before it fades from view.



Blue Snowball Nebula (NGC 7662)



1 Silver Sliver Galaxy (NGC 891)

Small telescopes show this galaxy of magnitude 9.96 as a faint needle of light, but larger telescopes reveal it is an edge-on structure with a bright central bulge and a dark dust lane running across its equator.

2 The Blue Snowball Nebula (NGC 7662)

Although this 8th magnitude planetary nebula can be seen through small telescopes, its blue colour is only visible through instruments 6-inches and larger.

3 Gamma Andromedae

Almach can be split with a small telescope, but larger instruments will highlight the beautiful contrast in colour between its bright pink-white component and its fainter, steely blue component.

4 Messier 110

If it wasn't so close to bright M31, M110 would be a popular object in its own right, but it is usually overlooked. Small telescopes show it as a small misty smudge; larger ones will show its subtle silvery beauty.

5 Messier 32

The smaller of M31's satellite galaxies is visible in small telescopes as a slightly brighter smudge within that great galaxy, but larger telescopes pull it out from the background glow.

6 Comet 64P/Swift-Gehrels

64P will be shining at magnitude 11 just over two degrees away from Mu Andromedae. Small aperture instruments should show it as an out-of-focus star, while larger instruments may pick out a faint tail.



© Hewholooks; Wikisky; Judy Schmidt



How to...

Observe the Andromeda Galaxy

This month we will help you navigate your way across the starry sky to find the most distant object you can see with your naked eye – M31, the great Andromeda Galaxy

You'll need:

- ✔ A dark observing site
- ✔ Our finder charts (On page 88)
- ✔ A pair of binoculars (optional)
- ✔ A small telescope (optional)

However much you dress it up with technical terms and scrawled equations, astronomy is basically the study of things that are very far away. Even the closest objects astronomers study – shooting stars, noctilucent clouds and the northern lights – are tens of kilometres above our heads. The Moon is almost 385,000 kilometres (239,000 miles) away, the Sun 146 million kilometres (91 million miles) away and the closest star is so many kilometres away that its light – travelling at 300,000 kilometres (186,411 miles) every second – takes over *four years* to reach us...

It stands to reason that out of all the billions of celestial objects out there, one must be the most distant the naked eye can see. Luckily for sky-watchers, this object, which is 2 million light years away, is something spectacular, and not just a faint star: M31, the great Andromeda Galaxy.

M31 is a huge spiral galaxy, larger than our own and containing hundreds of millions of stars. In around 5 billion years' time our Milky Way will collide with M31, and the two galaxies will merge into one.

Despite shining at magnitude 3.3, M31's large apparent size of 3 x 1 degrees – six times the size of the full Moon – means its light is spread over a wide area, giving it a low surface brightness. Consequently, any trace of light pollution will wash M31 from the sky; you will only see it if you're looking at a truly dark sky.

Once you've let your eyes adjust to the darkness you just need to do a bit of 'star hopping'. First find Cassiopeia, the distinctive W-shaped constellation of the Queen, then drop down to the upside-down 'Y' of Perseus (the Hunter) below it. That constellation's central star, Mirfak, is the starting point for a celestial hopscotch to the east along the line of stars forming Andromeda. Having reached Mirach, the third starry stepping stone along, you should see a small smudge above it – that's M31.

If it isn't immediately obvious try using the astronomers' trick of 'averted vision', which means looking just off to one side. This means the galaxy's faint light will fall on more sensitive parts of your retina and should become visible.

"In 5 billion years our Milky Way will collide with M31"

Tips & tricks

Chase the darkness

M31 is large and visible to the naked eye but is washed from the sky by even a small amount of light pollution. Go to the darkest sky near you.

Let your eyes adapt

Even from a dark site you won't find M31 right away. It will take at least half an hour for your eyes to 'dark adapt' enough for you to see it.

Find The Queen first

To start your M31 hunt, find the distinctive W-shaped constellation Cassiopeia, the Queen. You'll find it high in the east by the time the sky is dark enough to see M31.

Look at M31 from the corner of your eye

If you struggle to find M31 straight away look slightly off to one side of where it is in the sky and it should pop into view. Seasoned sky-watchers call this 'averted vision'.

© Kanwar Singh; Thomas Bresson

Getting Messier 31 in your sights

Make sure you're equipped for the very best views

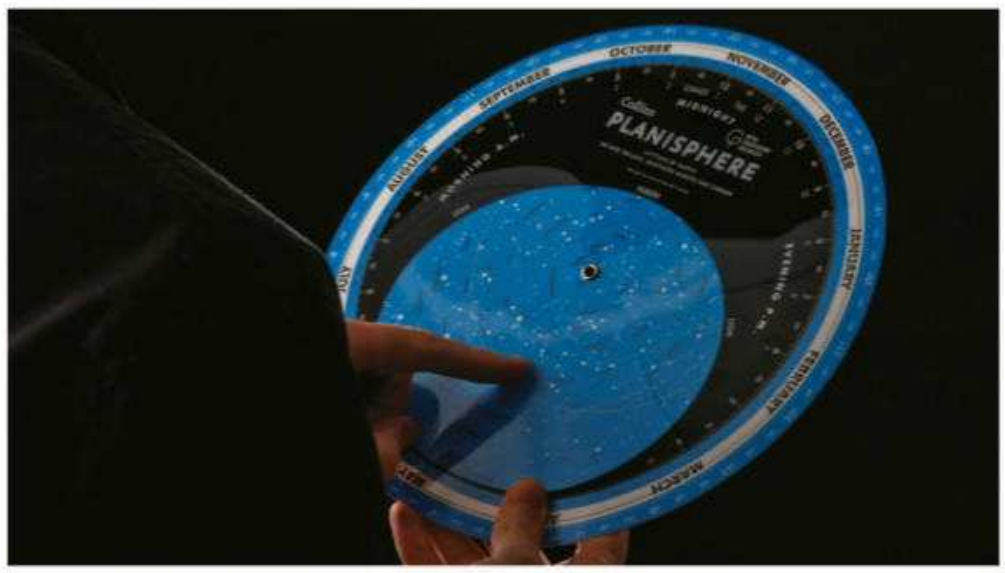
If your eyes refuse to show you M31, just centre Mirach in your binoculars and pan upwards very, very slowly. M31 will be there, a misty oval of grey light. If you have a small telescope it will show you M31 in even more detail. If the night is very dark you should be able to see hints of dark dust lanes in the galaxy, which will probably overflow your eyepiece's field of view.

Send your photos to
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1 Get dark adapted!

It's important to let your eyes adapt properly. M31's light is spread over a wide area and any light pollution or moonlight will hide it from view.



2 Find Cassiopeia

First, find Cassiopeia, a W-shaped constellation high in the east late in the evening. Then locate the upside-down 'Y' of Perseus directly below it.



3 Use star hopping to your advantage

Starting at Mirfak, the central star in Perseus, slowly 'star hop' two stars along to the right to Mirach in Andromeda.



4 Seek a smudge

Look for an elongated smudge of light a short distance above Mirach. This is Messier 31. Use averted vision if you don't see it right away.



5 Use binoculars

Use binoculars if you can't see M31 with just your eyes. You will see it as a distinct oval blur that is grey-white in colour.



6 Upgrade to a small telescope

Through a small telescope Messier 31 will look much brighter. You might even see one or both of its small satellite galaxies, M32 and M110.

STARGAZER

The Northern Hemisphere

The clocks go back at the end of this month, offering a splendour of night-sky objects for astronomers

Andromeda, Cassiopeia and Sculptor are just some of the constellations offering a selection of targets for telescope- and binocular-wielding astronomers this month. With the Sun dipping below the horizon earlier in the evening, those wanting to catch new or favourite targets don't have to wait long for dark skies to boast these treasures.

Head over to Andromeda and you'll be rewarded with not just its spiral galaxy, M31, but also its dwarf elliptical galaxies M32 and M110. While the parent galaxy is easy to spot, you'll need at least a medium-sized telescope to spot Andromeda's satellites. Star clusters are a joy to behold in the constellation of Cassiopeia, which can be spotted with ease by its 'W'.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.



Magnitudes

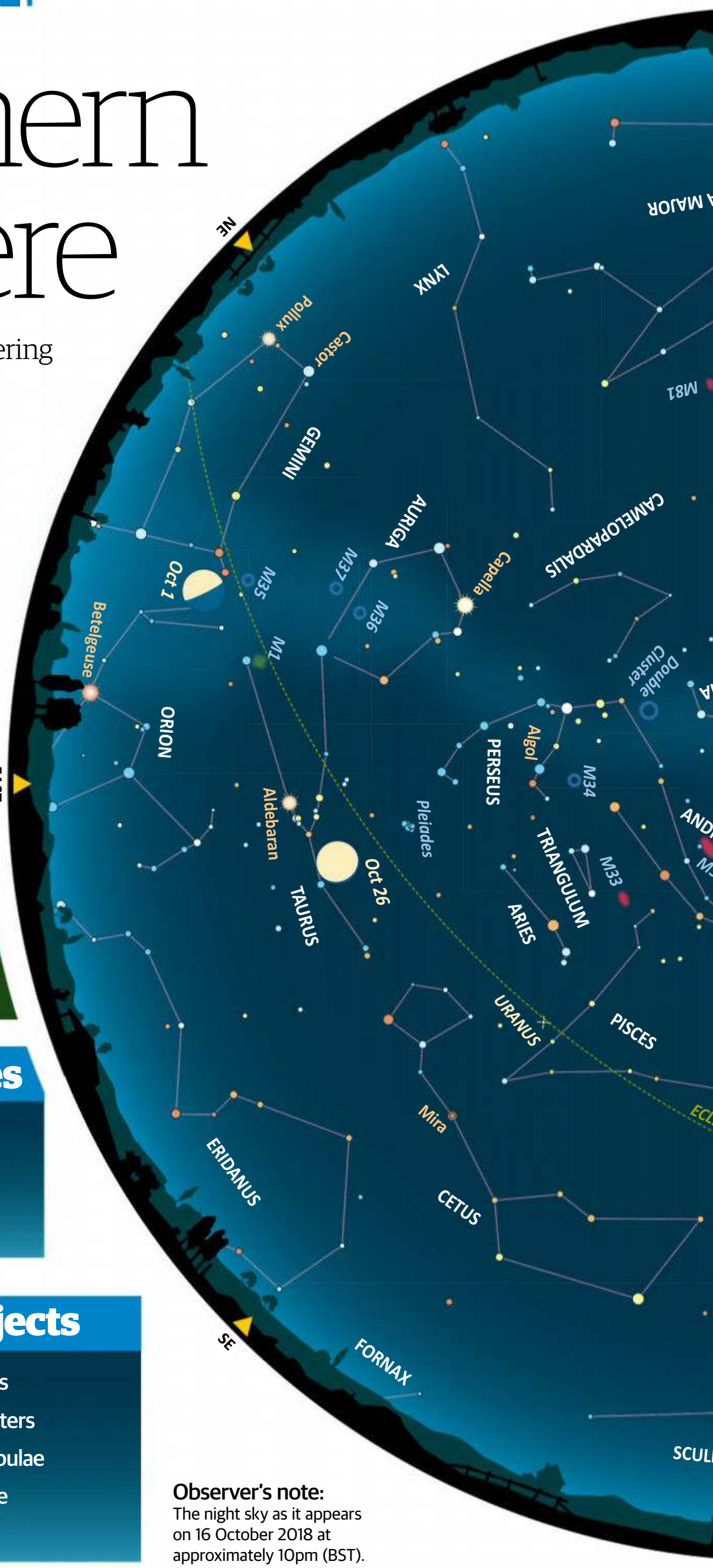
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- O-B
- A
- F
- G
- K
- M

Deep-sky objects

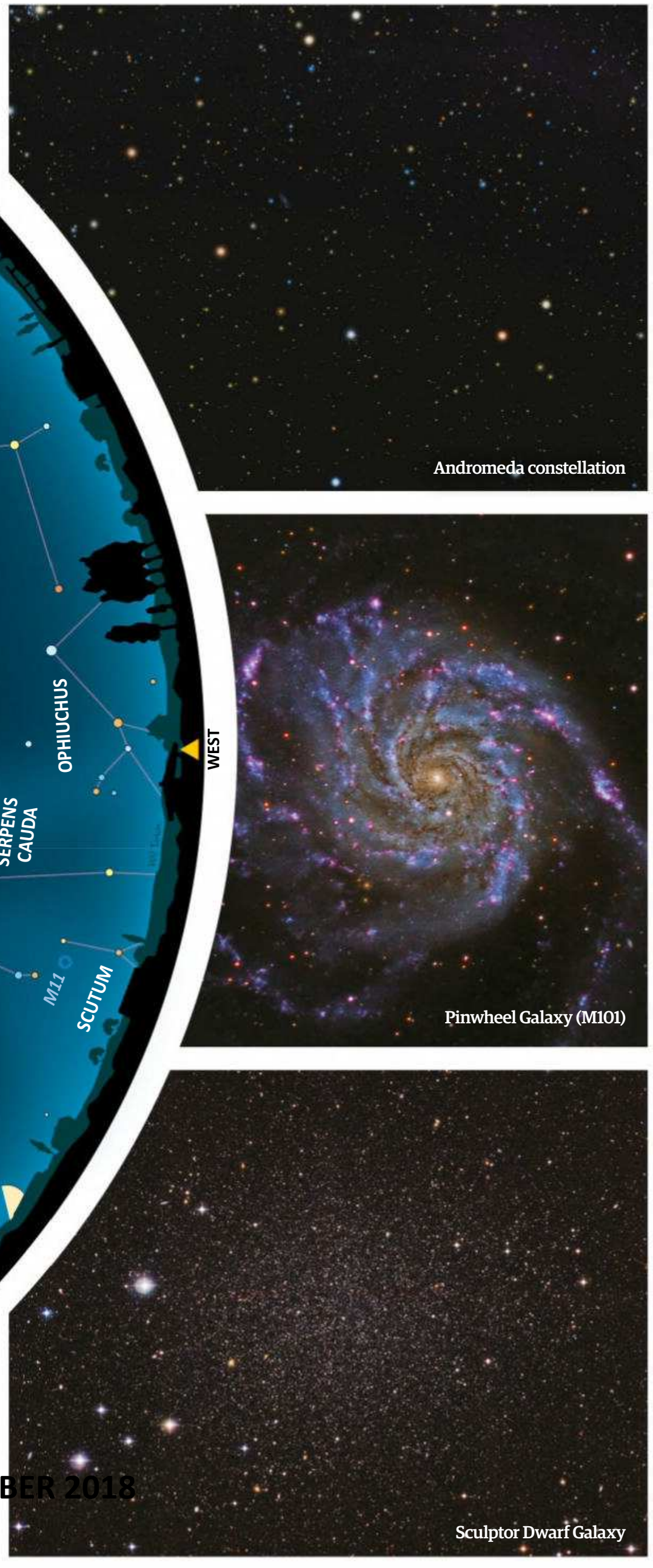
- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on 16 October 2018 at approximately 10pm (BST).

The Northern Hemisphere





Andromeda constellation

Pinwheel Galaxy (M101)

Sculptor Dwarf Galaxy

OCTOBER 2018

© Wil Tirion; ESO; KuriousGeorge; Roberto Mura

Astroshots *of the month*

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**

Orion Nebula (Messier 42)

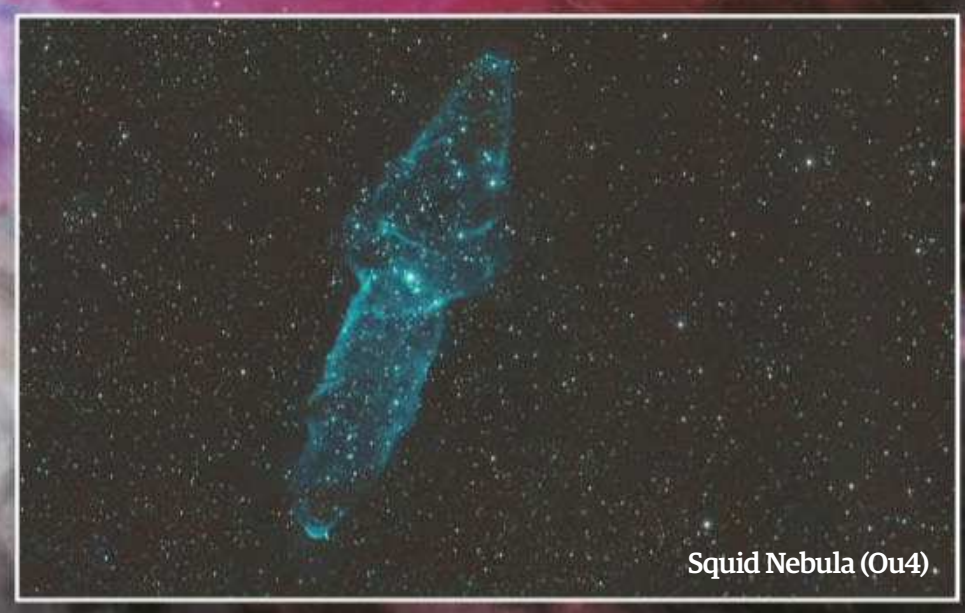
Paul Swift



Spain, Valencia
Telescope:
Vixen VSD 100 f/3

"Having had a background in the arts and working professionally as a cinematographer and lighting cameraman, astrophotography made for a natural change in focus. I had always wanted to turn my camera to the skies. A move away from London to Valencia, Spain presented me with the perfect opportunity to do just that.

"The combination of exploring deep space and the creative and technical art form that is astrophotography offered a powerful and alluring vocation. Any clear night I can be found setting up under darkening skies for a night of photography, and who knows, perhaps a new discovery."



Squid Nebula (Ou4)

Your astrophotography



The cratered surface of the Moon

Vicki Pink



Southampton, Hampshire
Telescope: Sky-Watcher Explorer 130P AZ

"I purchased my first 'scope in May. It's a Sky-Watcher Explorer 130P AZ GoTo. I image using my Huawei P20 in Pro mode. That was the start of my journey into astronomy.

"My first astroimage was a single handheld image, pretty basic. Since then I've learned to use various computer software. I crop in PIPP, stack in Autostakkert!2 and use wavelets in RegiStax 6. I'm learning an awful lot and belong to various astronomy groups where advice is second to none. I can't believe how much I've learned in so little time - I can't wait for greater things."



Saturn

Graham Hard



London, UK
Telescope: Sky-Watcher 250PDS

"I took up astrophotography in April 2012. I soon realised that galaxies and deep-sky objects were very limited with regard to viewable detail, so I started looking at how to photograph these objects and was immediately hooked. Now I will often collect image data of 12 or more hours to produce my images. I love to image all aspects of the night sky: comets, planets, the Sun, the Moon and all galaxies and nebulae. Where I live the night sky is very poor so I am experimenting with narrow-band imaging, which can improve the negative effect of light pollution."



Send your photos to... @spaceanswers @space@spaceanswers.com

Omegon Advanced X N 203/1200 dobsonian

A telescope that is an all-rounder when it comes to observing the Solar System and deep-sky targets, this reflector is suitable for all levels of astronomer on a tight budget

Telescope advice

Cost: £313 (approx. $411)
From: Astroshop.eu
Type: Reflector
Aperture: 7.99"
Focal length: 47.24"

Best for...

- Beginners to advanced
- Medium budget
- Planetary viewing
- Lunar viewing
- Deep-sky objects
- Family

Dobsonian telescopes are considered the ultimate all-rounder instruments for beginners, however, on trying out the Omegon Advanced X N 203/1200, we soon realised that this instrument's simplicity not only lends itself to anyone starting out in the hobby of astronomy, it's also a great telescope for the veteran of the night sky.

The reflector arrived in parts, which meant that some construction was required – a process that took roughly 30 minutes. While most of the tools were supplied in assembly, such as the screws and allen keys, you'll need to supply a Philips screwdriver in order to tighten some of the fastenings. Building a dobsonian is something that may put off someone who is new to observing, but we'd argue that once it has been constructed, no further assembly is needed. The 8-inch telescope slots snuggly into a wooden rocker box, which also features a four-slot eyepiece holder that's able to take a couple of 1.25-inch eyepieces as well as two 2-inch eyepieces. Meanwhile an inbuilt clutch system allows enough tension if you find that your eyepieces are heavy enough to tilt the telescope's rocker box.

The focuser doesn't come attached to the telescope tube, something that will come immediately apparent on unboxing the instrument. You'll need to attached this separately – that was a bit of an issue with the supplied allen keys. In the end, we had to use our own set in order to fit this piece of the set up securely. The dobsonian is supplied with two 1.25-inch eyepieces – a 25mm and a 10mm – an extension tube for the focuser as well as a useful zero magnification red-dot finder.

We put the Advanced X N to the test under a late summer sky where Altair, the brightest star in the constellation of Aquila, was our primary focus. Using the 0.77-magnitude star, we were able to test the clarity of the field of view, which remained sharp for up to 80 per cent of it through the 25mm eyepiece before the star became distorted close to the edges. However, this wasn't a deal-breaker since the same eyepiece provided superb views of a selection of night sky objects; detailed sights of Messier 27, also known as the Dumbbell Nebula, were had, whilst slewing over to Hercules gave us very good views of globular cluster Messier 13. Switching to the 10mm showed us a gathering of densely-packed stars and the Ring Nebula (Messier 57) in Lyra was certainly an impressive sight in the field of view.



The Omegon Advanced employs a Crayford focuser



The telescope makes use of a red-dot finder

The Omegon SkyQuest XT8 is useful for beginner and more seasoned astronomers

Heading over to Andromeda, its famous resident galaxy Messier 31 could almost fit into the field of view using the 10mm eyepiece. The 25mm gave us a much more zoomed-in sight, with only half of our neighbouring spiral visible. Taking a further tour of the night sky, we enjoyed splendid views of NGC 6207, a magnitude +11.6 galaxy close to Messier 13, before spotting galaxy NGC 7331 as a smudge in Pegasus.

Having a decent aperture, we were keen on seeing how the Advanced X N fared during observations of open clusters. Luckily for us, the Wild Duck Cluster (Messier 11) was well placed for observation in the constellation of Scutum - both clusters were framed beautifully by both eyepieces, where the member stars sparkled impressively and with clarity. The Advanced X N also made short work of splitting double stars, cleanly separating Albireo in Cygnus into gold and blue components and Iota Cassiopeia into its three member stars.

Looking quite a few light years closer to Earth, Solar System targets Mars and Jupiter were impressive in the field of view, especially with the help of filters to enhance them for contrast. Jupiter's bands and largest moons, Io, Europa, Callisto and Ganymede were clear to see as points of light either side of the gas giant's limbs. A familiar sight for veterans of the night sky, but nethertheless a breathtaking sight for all levels of astronomer. The Moon, which at the time, took pride of place in the night sky in the small hours as a waxing gibbous phase, was beautiful in the field of view; craters and lava fields on the lunar surface appeared pin-sharp along the terminator.

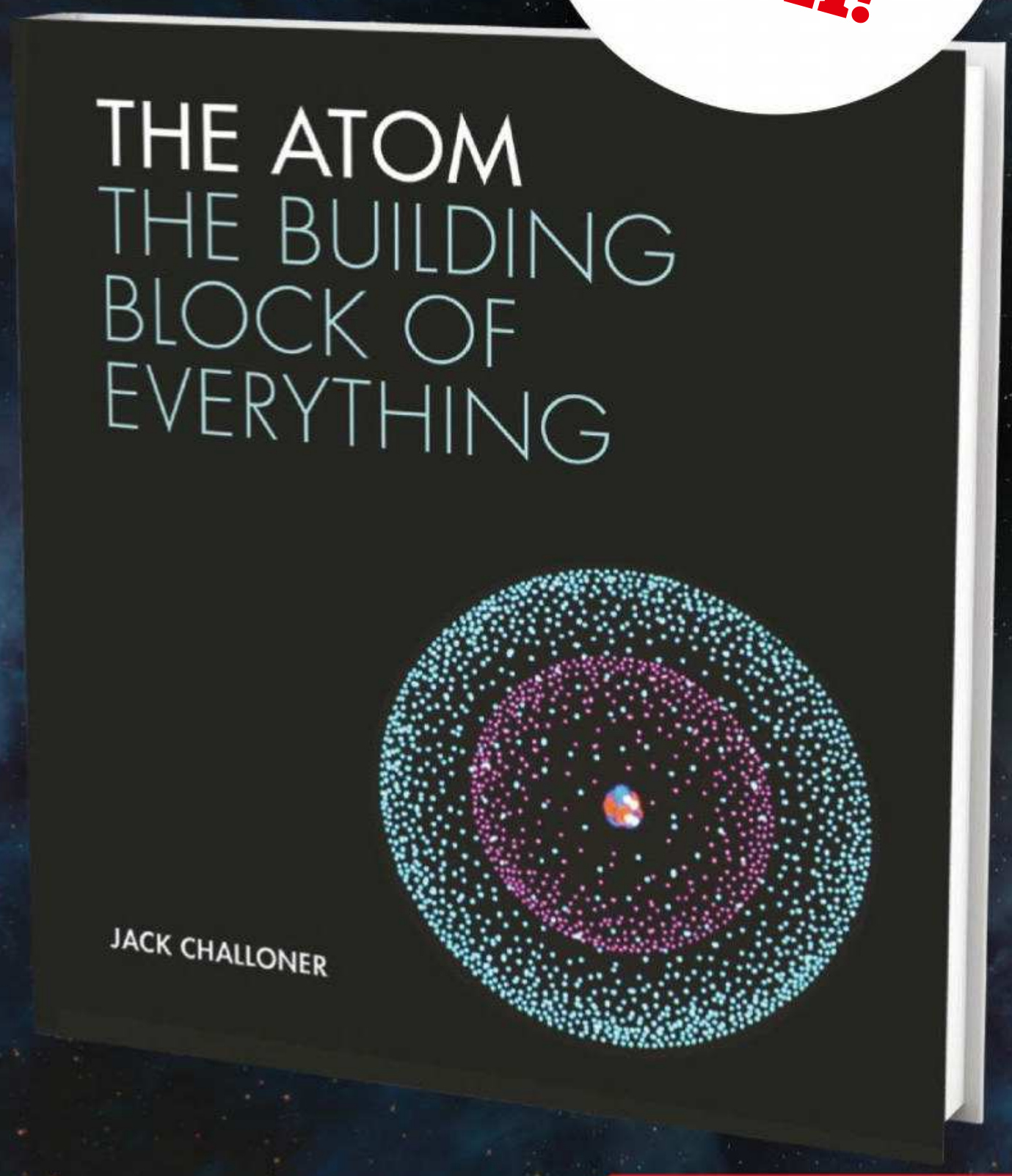
There's no doubt about it, this dobsonian - despite its cumbersome size - achieves a sterling performance. Whether you're a beginner or a seasoned astronomer, the sights it sports are a must-see and, provided you accessorise the instrument, is a perfect companion for many years to come. You won't need for you to upgrade your kit for years to come - if ever!

WIN!

ONE OF TEN COPIES OF THE ATOM

Courtesy of Quarto Publishing, here's everything you need to know about the building blocks of the universe

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Congratulations to Jonathan Daniel, who is the winner of the Sky-watcher Explorer 130-PS (AZ5) telescope



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STARGAZER

In the shops

The latest books, apps, software, tech and accessories for space and astronomy fans alike

Book Planetarium

Cost: £20.00 **From:** Templar Publishing

Aimed at children between 9 and 11 years old, *Planetarium* is 112 pages of stunning galleries of galactic matter that have been beautifully curated to bring the experience of a fascinating exhibition from the comfort of your own home – through the artwork of Chris Wormell and informative prose from astronomer Professor Raman Prinja of University College London, where he specialises in massive stars, star formation and the evolution of galaxies. To ensure that no region of space is left unexplored, *Planetarium* – which has been made in collaboration with the Science Museum – expertly begins from our nearest star the Sun, out to our Solar System, heading out to look into the lives of stars and to the outer reaches of our Milky Way and the universe beyond it.

While *Planetarium* is aimed at the younger generation, we couldn't help but think that adults would get quite a bit of enjoyment leafing through its pages too, making it the ideal book to not just have in your child's library but also on your coffee table for those lazy days on the sofa.

Music & Movie Voyager

Cost: £11.00 **From:** Market Square Music Ltd

Made by electronic composer and performer Warren Greveson, *Voyager* is the music and movie celebration of the longest-running space trip by the spacecraft of the same name. The combined CD and DVD traces the launch and 40-year journeying of the twin craft in a two-disc package, synchronised into a specially commissioned 70-minute-long film dubbed *Hello from Planet Earth*.

Voyager was released on the 41st anniversary of the launch of Voyager 1 this year and is made up of two parts entitled *Journey to Jupiter* and *Saturn and Beyond*, which have been broken down into nine tracks each and begin with recordings of 55 greetings in different languages – you'll remember that these are also featured on the gold disc carried on the spacecraft. The CD also features sounds of the solar wind and the universe as recorded by Voyager and ends on 'the legacy: the impact that the Voyager project has had on all of us'. Pleasing and intriguing both visually and to the ear, *Voyager* is perfect for any space fan – and with Christmas just around the corner, we think it should be firmly on the present list!

> "With Christmas around the corner, *Voyager* should be firmly on the present list"

App GoSkyWatch Planetarium

Cost: £2.99/$3.99 **From:** iTunes

GoSkyWatch Planetarium is easy to download and seems to respond well to constant use on an iPhone 6 without overheating our device, crashing, freezing or any glitches. Given its high performance graphics and the amount of information it stores – including 200 images of planets and deep-sky objects, Moon phase calendar, sunrise and set times – the planetarium does take up a good proportion of memory.

When fired up, the sky was immediately correctly orientated no matter how our phone was tilted, meaning that we weren't restricted to a portrait or landscape view of the night sky. The app's graphics are pleasing to the eye and packed with detail – some may be put off by GoSkyWatch only showing naked-eye stars, but we think that the 'sky view' looks a lot less cluttered and confusing – especially to those who are just learning their way around. Pinching the night sky allows you to see an entire dome of stars as well as those below the horizon, while stretching enabled us to zoom into sections of interest.



Software AstroPlanner v2.2

Cost: Free **From:** astroplanner.net

For those who are just getting into astronomy and are looking for assistance from an astronomy software to learning the night sky, AstroPlanner can look quite frightening. However, once you get the hang of using this free software – that's compatible with Macintosh and Windows – it's useful to have in your observing arsenal. AstroPlanner not only allows you to plan and log your observations, it allows you to control telescopes with computerised GoTo mounts as well as those with digital setting circle controllers.

AstroPlanner uses a large main window to allow you to plan your night of observations. At this window you are able to enter or view information on the objects you wish to see, observations and field of view. Once these are complete you get a view – as it would appear through your telescope – of your chosen object. The software allows you to find your object on its database, but we did note that not all of the objects we wanted to observe were listed. Adding objects, however, wasn't a problem. On the hugely positive side, AstroPlanner provides a lot of useful information on each target that is listed.

HEROES OF SPACE

Wang Zhenyi

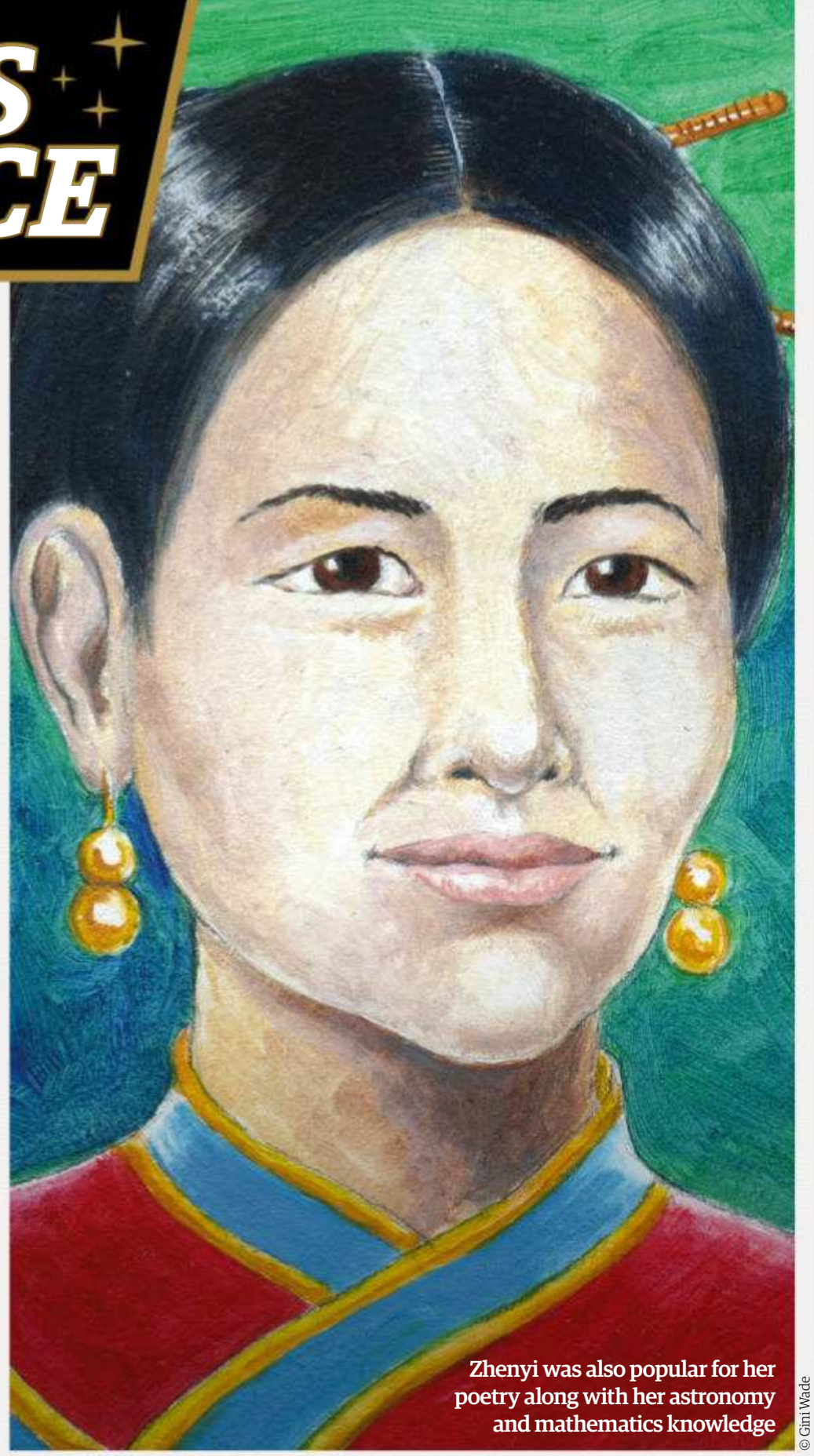
She was a strong female astronomer of the Qing dynasty

Wang Zhenyi is not considered a household name, but her knowledge was ahead of her time in China. She lived a short life, sadly dying at the age of just 29, a shame considering her vast knowledge of astronomy and mathematics and the potential she had to further this.

Zhenyi was born in China in 1768, which is the same year that China's Emperor Qianlong had to wage a campaign against rumoured sorcerers roaming around the country stealing souls. Born into the Qing Dynasty, Zhenyi moved to Jiangning - now named Nanjing - with her grandfather Wang Zhefu; grandmother, neé Dong, and her father Wang Xichen. Zhenyi's father failed the imperial examination and went into medical science, while her grandparents were her first teachers in astronomy, mathematics and poetry.

Her grandfather passed on his passion for reading and had an extensive library consisting of over 75 books. After his death in 1782 the family moved to Jiling, which was close to the Great Wall, and in the following five years Zhenyi gained her extensive knowledge from his library, as well as learning about equestrian skills, archery and martial arts from the wife of a Mongolian general named Aa.

Zhenyi's contributions to astronomy and mathematics were incredibly influential, and she was one of few that was able to explain and prove astronomical phenomena. She was able to explain equinoxes, writing *Dispute of the Procession of the Equinoxes*, and wrote about other aspects, such as *Dispute of Longitude and Stars* and *The Explanation of a Lunar Eclipse*.



Zhenyi was also popular for her poetry along with her astronomy and mathematics knowledge

© Gini Wade

One of the experiments she constructed was able to explain and study eclipses by using different things 'around the house' in place of celestial objects. She placed a round table in a garden pavilion which acted as Earth, a crystal lamp was hung from the ceiling beams from a cord, acting as the Sun, and a mirror was used as the Moon. By moving the figurative Moon, Earth and Sun, an accurate understanding of astronomical events was recorded in her extraordinary work, *The Explanation of a Solar Eclipse*.

Venturing over to the closest related field of mathematics, Zhenyi was a scholar and promoter of the Pythagorean Theorem, having also written another article entitled *The Explanation of the Pythagorean Theorem and Trigonometry*. Her ability to simplify maths opened up the world for many Chinese people, having written the book *The Simple Principles of Calculation* at 24.

At the age of 25 Zhenyi married Zhan Mei, but they did not have any children together. Only four years later she passed away. She blazed a trail for not only female scientists hundreds of years ago, but for Chinese astronomy in general. Her self-taught ability to explain astronomical events and simplify the complexities of mathematics is a skill that should be remembered and appreciated.

"Zhenyi's contributions to astronomy and mathematics were incredibly influential... she was able to explain astronomical phenomena"

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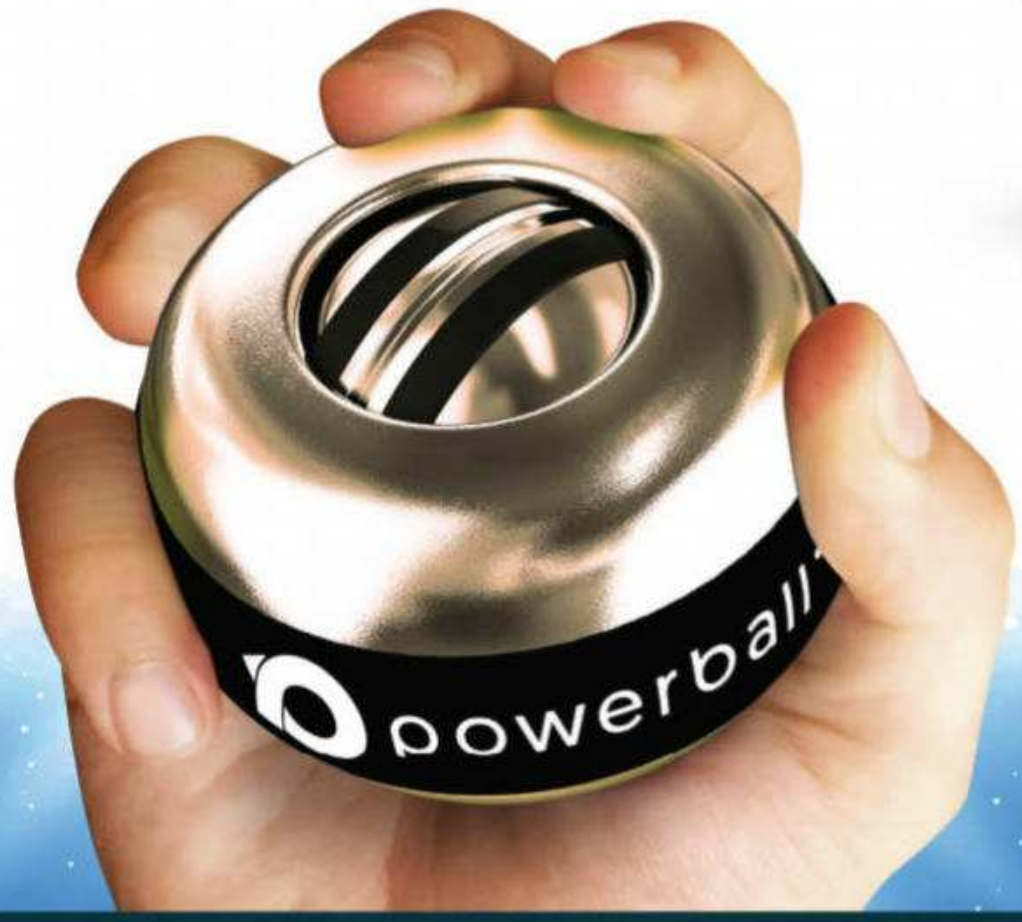


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Sky-Watcher®

AZ PRONTO & AZ5 Alt-Azimuth Telescopes

These new lightweight and highly portable grab-and-go telescope ranges combine the thoughtfully designed and well-engineered AZ PRONTO and AZ5 DELUXE Alt-Azimuth mounts with proven high quality Sky-Watcher optics. Each model comes complete with an adjustable aluminium tripod with accessory tray and supplied with two manual flexible slow-motion cables, for easy vertical and horizontal fine motion control. Tracking is smooth and precise via their continuous worm-gear movements. The mount can also be moved around each axis manually, for rapid panning and elevation adjustments. It is often said that the best telescopes are the ones which get used most often - These new ranges are quick to assemble, extremely easy to use and are refreshingly brilliant in their convenient functional simplicity, that will encourage regular use by both beginners and seasoned observers alike!

AZ PRONTO ALT-AZIMUTH RANGE

SRP £219

Prod.Code 10272



EXPLORER-130PS (AZ PRONTO)

130mm (5.1") f/5 PARABOLIC NEWTONIAN REFLECTOR

With an extremely useful 130mm of light gathering aperture and a superb parabolic primary mirror, this is a highly capable all-rounder for the observation of the Moon, bright planets, nebulae, galaxies and star clusters. Supplied with 10mm & 25mm Eyepieces and Red Dot Finder.

SKYMAX-102 (AZ PRONTO)

102mm (4") f/12.7 MAKSUTOV-CASSEGRAIN

The Maksutov's high-resolution multi-coated optical system, excels at medium-to-high powers for the examination of the surface detail of the Moon, planets and also for double-star observations. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

SRP £299

Prod.Code 10270



SRP £259

Prod.Code 10271



EVOSTAR-90 (AZ PRONTO)

90mm (3.5") f/10 REFRACTOR

A classic two-element, air-spaced, multi-coated achromatic refractor. With its long focal length it is ideal for the detailed high-power study of the Moon & planets. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

AZ PRONTO MOUNT & TRIPOD
Prod.Code 20317 **SRP £139**

AZ5 DELUXE ALT-AZIMUTH RANGE

STARTRAVEL-102 (AZ5)

Prod.Code 10261

102mm (4") f/4.9 REFRACTOR

Ideal multi-coated instrument for the widefield observation of deep-sky objects, such as nebulae, star fields, star clusters and galaxies. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.



SRP £379

AZ5 MOUNT & TRIPOD
Prod.Code 20311
SRP £229

AZ5 MOUNT HEAD ONLY
Prod.Code 20312
SRP £159

SRP £299

Prod.Code 10260



EXPLORER-130PS (AZ5)

130mm (5.1") f/5 PARABOLIC NEWTONIAN REFLECTOR

With an extremely useful 130mm of light gathering aperture and a superb parabolic primary mirror, this is a highly capable all-rounder for the observation of the Moon, bright planets, nebulae, galaxies and star clusters. Supplied with 10mm & 25mm Eyepieces and Red Dot Finder.

SRP £499

Prod.Code 10262



SKYMAX-127 (AZ5)

127mm (5") f/11.8 MAKSUTOV-CASSEGRAIN

The Maksutov's high-resolution multi-coated optical system, excels at medium-to-high powers for the examination of the surface detail of the Moon, planets and also for double-star observations. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

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